

THE IMPACT OF REPEATED EARTHQUAKES ON THE  
COGNITION OF CANTERBURY'S ELDERLY  
POPULATION

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## Abstract

**Objective:** The nature of disaster research makes it difficult to adequately measure the impact that significant events have on a population. Large, representative samples are required, ideally with comparable data collected before the event. When Christchurch, New Zealand, was struck by multiple, devastating earthquakes, there presented an opportunity to investigate the effects of dose-related quakes (none, one, two or three over a 9-month period) on the cognition of Canterbury's elderly population through the New Zealand Brain Research Institute's (NZBRI's) cognitive screening study. The related effects of having a concomitant medical condition, sex, age and estimated- full scale IQ (Est-FSIQ) on cognition were also investigated.

**Method:** 609 participants were tested on various neuropsychological tests and a self-rated dementia scale in a one hour interview at the NZBRI. Four groups were established, based on the number of major earthquakes experienced at the time of testing: "EQ-dose: None" (N = 51) had experienced no quakes; "EQ-dose: One" (N = 193) had experienced the initial quake in September 2010; "EQ-dose: Two" (N = 82) also experienced the most devastating February 2011 quake; and "EQ-dose: Three" (N = 265) also the June 2011 quake at testing.

**Results:** Two neuropsychological variables of Trail A and the AD8 were impacted by an EQ-dose effect, while having a medical condition was associated with poorer function on the MoCA, Rey Copy and Recall, Trail A, and AD8. Having a major medical condition led to worse performance on the Rey Copy and Recall following the major February earthquake. Males performed significantly better on Trail A and Rey Planning, while females better on the MoCA. Older participants (>73) had significantly lower scores on the MoCA than younger participants (<74), while those with a higher Est-FSIQ (>111) had better scores on the MoCA and Rey Recall than participants with a lower Est-FSIQ. Finally, predicted variable analysis (based on calculated, sample-specific Z-scores) failed to find a significant earthquake effect when variables of age, sex and Est-FSIQ were controlled for, while there was a significant effect of medical condition on each measure.

**Conclusion:** The current thesis provides evidence suggesting resilience amongst Canterbury's elderly population in the face of the sequence of significant quakes that struck the region over a year from September 2010. By contrast, having a major medical condition was a 'more significant life event' in terms of impact on cognition in this group.

## **Introduction**

### **New Zealand, Dementia, and Neuropsychological Testing**

In 2011, 1.1% of the New Zealand population had some form of dementia (Dementia Economic Impact Report, DEIR, 2011). By 2050, that proportion is estimated to have risen to 2.6%, as the current majority ‘baby boomer’ population reaches retirement and beyond (DEIR, 2011). What is concerning is that the World Alzheimer Report (2011) reported that only 60% of cases of dementia are diagnosed or documented in countries such as New Zealand. Further, there is a significant proportion of the population who experience significant cognitive impairment, but who maintain relative independence of instrumental activities of daily living (ADLs) and thus do not qualify as having dementia (American Psychiatric Association, 2014). These individuals are usually described as showing Mild Cognitive Impairment (MCI), the prevalence of which varies from 2-20% depending on how it is measured (Petersen, 2011; Plassman, Langer, Fisher, et al., 2008; as cited in Langa and Levine, 2014). MCI and dementia are significant health issues in New Zealand, with the financial cost of dementia in 2011 estimated at \$954.8 million (DEIR, 2011).

A variety of neuropsychological tests are used to assess cognition, necessary to diagnose dementia and MCI, along with assessments of everyday functioning to determine whether a dementia diagnosis is warranted (DSM-5, 2013). These neuropsychological tests are sensitive to ongoing changes to cognition over time, and may identify individuals who are in the ‘pre-disease’ phase of dementia, or MCI, who generally are at a greater risk of developing dementia (Langa & Levine, 2014). Neuropsychological tests also have value in assessing the effects of exogenous stressors (as well as endogenous) on cognition, and whether those stressors have long-lasting consequences for those affected (Langa & Levine, 2014).

### **The Canterbury Earthquakes**

The clinical and economic impact of dementia in New Zealand now, and in the very near future, makes it one of the most pressing health concerns facing this small country. It is of value, therefore, to undertake any opportunity to study stressful events that can potentially cause or exacerbate cognitive decline in susceptible individuals. An obvious issue then is the potential impact that natural disasters have on the aged and people with MCI, who are at increased risk of succumbing to dementia. The city of Christchurch and the surrounding

region, New Zealand, with a population of 400,000 people, was struck by a sequence of major earthquakes, in addition to many thousands of lesser yet substantial earthquakes, starting in September 2010, which persisted over a period of two years and with more infrequent quakes occurring up to the time of submission of this thesis. The period of substantial quakes presented a unique natural study to study their effect on elderly and vulnerable members of this region.

Three major earthquakes stood out as being the most damaging seismic events: September 4, 2010; February 22, 2011; and June 13, 2011; which measured 7.1, 6.3 and 6.4 on the Richter scale, respectively (<http://www.christchurchquakemap.co.nz/>). The additional quakes that also had an impact ran to more than 400 that measured greater than Richter 4.0, over 3000 greater than 3.0, and another 10,000 greater than 2.0. In the most significant event, on the 22 of February, 2011, 185 people lost their lives when Christchurch was shaken by a rapid uplift, one of the most violent earthquakes ever measured (based on peak ground acceleration readings, Lin & Allen, 2011). This February earthquake resulted in wide-spread damage to the city centre, the whole infrastructure of the city and almost every home, perhaps 5% irreparably (Parker & Steenkamp, 2012) many of which to this date are yet to be rebuilt while the land under others has been “red-zoned” (no rebuild allowed). These events put the inhabitants of this city under considerable, prolonged stress, beyond the obvious trauma; with some unable to retrieve any of their possessions and about 25% dealing with difficult and ongoing insurance claims (Parker & Steenkamp, 2012).

The New Zealand Brain Research Institute (NZBRI) had begun a screening programme in Canterbury for volunteers aged over 65 in the months preceding the initial Canterbury earthquake of September 2010. The aim of the project was to screen eight hundred participants aged 65 years and over from the Canterbury region in a longitudinal study to assess memory, attention and language with neuropsychological assessments and self-report questionnaires. The study was to identify those with a high risk of progressing to dementia, specifically Alzheimer’s disease (AD), by determining the subset of participants who showed evidence of MCI based on their neuropsychological assessment. It was anticipated that individuals on the cusp of dementia might benefit most from a cognitive enrichment intervention that was to be introduced to these participants.

Of relevance to this thesis, a significant number of participants were inducted into the NZBRI screening programme before, during and after the series of major earthquakes that

devastated the city and surrounding areas. There was an impression that these earthquakes were having an effect on the overall wellbeing of these participants. The term “quake-brain” became popular in the months following the major earthquakes and the general feeling in many people turned from acute anxiety to overwhelming stress, including the many obstacles for rebuilding homes and essential infrastructure (see Crowe, 2011, for a Cantabrian’s perspective months after the February 2011 earthquake). There is relatively little research on the effects that natural disasters have on cognition and especially those who have experienced multiple traumatising events, especially for the duration of major events in Christchurch. Hence, the aim of the current study was to examine whether there was a negative linear relationship between increasing ‘dose’ of earthquake and cognitive performance on a range of neuropsychological assessments across older volunteers who were recruited at different points during the sequence of earthquakes experienced in Christchurch.

Initially, this thesis will review research conducted on the effects of endogenous as well as exogenous stressors on cognition. Next, the current literature on natural disasters will be examined to identify what is already known about the impact on those who experience them. Identifying those who experience negative consequences from traumatising events may make it possible to target individuals who may benefit from assistance and post-disaster follow-up care in an attempt to limit any potential long term consequences. There may also be identifiable protective factors that may be relevant. These findings will then form the basis for the development of hypotheses to investigate in this opportunistic environment.

## **Stress and Cognition**

There is vast literature on stress and cognition. When one thinks of stress, many definitions are available. From its original use as an engineering term to explain when forces put strain on a structure, it was borrowed in 1936 by Hans Selye to explain a “non-specific phenomenon representing the intersection of symptoms produced by a wide variety of noxious agents” (pg.210, Lupien, Maheu, Tu, Fiocco & Schramek, 2007; Selye, 1998). Now, it is generally accepted that almost anything can be described as a ‘noxious agent’ if it indeed causes a stress response in an individual- whether that is expected or not in the circumstances. According to Lupien, Ouellet-Morin, Hupback, Walker, Tu, and Buss (2006), the stressful agent can be *absolute*, in that it is a real threat either witnessed or experienced (such as witnessing an accident, or the threat of a natural disaster), or it can be *relative*, in that the implied threat is induced by the interpretation of a situation as being novel, unpredictable



and/or uncontrollable (such as sitting an exam). Therefore, most, if not all of the population will experience the stress associated an absolute threat, whereas relative stressors will elicit a stress response only in a certain proportion of individuals.

Describing stress is important in the context of cognition, and highlights that there are a range of stressors that may or may not have the same impact on individuals, depending on their absolute or relative status. For example, it would be reasonable to assume a natural disaster will cause stress for the majority, if not the totality, of the population, compared with an event such as public speaking. The literature on the effect stress has on cognition has grown and the association has not always been straight forward. Nevertheless, there is sufficient evidence to suggest that stress, and the accumulative effect of experiencing multiple stressful events, leads to a significant decline in cognitive performance, if the event produces a significant enough stress response in the individual (Lupien et al., 2007).

It is well established that cortisol, a corticosteroid released by the zona fasciculata of the adrenal cortex, with the primary function to increase blood sugar through gluconeogenesis, is released in periods of stress and suppresses the immune system and aids the metabolism of fat, protein and carbohydrate (Lundberg, 2000; Marieb & Hoehn, 2010). A recent review of the literature found that salivary cortisol is a “clear indicator of stress in both children and adults” (pg.960, Aguilar Cordero et al., 2014). The consequences of chronically raised cortisol include: reduced immune function, affecting healing and thus prolonging recovery time; delayed growth in children; and increased blood pressure and heart rate in both children and adults. Of particular relevance, doses of glucocorticoid (cortisol) given to healthy adults over a three day period, which equated to the blood levels of cortisol seen in physical or psychological stress in humans, have been shown to produce a reversible reduction in verbal declarative memory (Newcomer et al., 1999).

In a major review, Lupien et al. (2007) summarised studies that had investigated the effects a rise in endogenous and exogenous stress hormones had on human cognitive performance. Clear associations between increased corticosteroid exposure and decreased event-related potentials have been demonstrated (Kopell, Wittner, Lunde, Warrick, & Edwards, 1970), which aligned with early clinical observations made by Henkin, McGlone, Daly, and Bartter (1967), suggesting that “glucocorticoids act by inhibiting the central nervous system, possibly leading to a state of hypovigilance” (pg. 215 Lupien et al., 2007;

adapted from Henkin et al., 1967), a phenomenon also observed after treating Addison's disease patients.

Beyond central nervous system hypovigilance, Lupien et al. (2007) reported evidence of negative effects of exogenous glucocorticoid on the hippocampus and declarative memory (Lupien & McEwen, 1997; de Quervain, Roozendaal, Nitsch, McGaugh, & Hock, 2000; an *in vivo* demonstration: de Quervain, Henke et al., 2003; Buss, Wolf, Witt, & Hellhammer, 2004), the frontal lobe and working memory (Young, Sahakian, Robbins & Cowen, 1999; Lupien, Gillin & Hauger, 1999; Hsu, Garside, Massey & McAllister-Williams, 2003) and emotional memory (see review by Damasio, 1995). However, enhanced recall of emotionally arousing pictures was found by Buchanan and Lovallo (2001) and further beneficial effect of synthetic glucocorticoids in both emotionally arousing and neutral material was reported by Abercrombie, Kalin, Thurov, Rosenkranz and Davidson (2003).

Lupien et al. (2007) also summarised evidence that 'stress', when applied to rats either before or after learning, or before recall, induced elevations in glucocorticoid levels and changes in declarative memory that followed an inverse U-shaped function, similar to observed effects of exogenous glucocorticoids on human cognition (Roozendaal, 2002). In humans, more recent laboratory studies have also confirmed that high glucocorticoid levels (following this inverse U-shaped function) are associated with memory impairments (e.g. recall of neutral word lists) following tasks that would induce stress (such as a public speaking task) as demonstrated by Jelici, Geraerts, Merckelbach, and Guerrieri (2004; see also Lupien, Buss, Schramek, Maheu, & Pruessner, 2005).

Further, Lupien et al. (2007) also concluded that the emotional content of the to-be-remembered material may have an influence on its recall with stress-related elevations in glucocorticoids having varying effects. In other words, if the stressor is emotionally arousing itself then recall of the events related to the stressor will be enhanced (in contrast to the above stated inverse U-shaped function), whereas there will be poor memory recall of material unrelated to the source of the stress. That is, cortisol levels may not be as important as the "valence" of the material learned (Jelici et al., 2004). In an evolutionary sense, it would be wise to put less important material to the back of one's mind during a stressful event, so that efforts could be put into learning as much as possible from the stressor (with emotion playing a key part in enhancing memory acquisition, and subsequent recall. The downside of this

process is that recall of previously learned (unrelated) information will be jeopardised, and possibly lost, regardless of how important it may have been at that particular time.

### **Measuring the Effect of Naturally Occurring Stress**

Two factors not yet considered are natural stress and its impact on memory (compared to laboratory-induced stress), and chronic stress when there may be a cumulative effect on memory and cognition. Evaluating a cognitive response to stress in a natural environment is extremely difficult, due to the subjective nature of ‘stress’ - and, therefore, the ability to predict when a stressful event will occur for an individual. One way of studying this phenomenon, however, is to look at natural disasters. The current thesis examined the specific impact of the Canterbury earthquakes on the cognition in the elderly. Another study has investigated the effect of the Canterbury earthquakes on Sustained Attention to Response Task (SART) performance in University of Canterbury students. Students who indicated a “greater cognitive disruption induced by an earthquake” (pg. 1735) performed significantly worse on the SART than those who did not self-report any (subjective) change in cognitive function. The SART is a low No-Go target detection task, used to measure lapses of attention (Helton, Hemp & Kemp, 2011). It is possible, then, that cognitive impairment in the elderly might be associated with the ongoing quakes, which this study assessed.

The research into natural disasters (or any major event in one’s life) and the effects on human cognition are mixed in their quality and quantity, due to the random and largely unpredictable nature of these events. Collectively, natural disasters usually affect a large number of people and occur on a regular basis, and with no discrimination of age, race, religion or sex. While most of the world’s population are at risk of being affected by a natural disaster, the scant literature makes this an area of research that needs more attention. Anxiety and depression are the obvious measures to look at immediately following a traumatic event such as a natural disaster; however, the ongoing effects of having experienced an emotionally arousing event may extend beyond psychological distress. Certain events may contribute to the cognitive decline above and beyond that of normal aging or any disease process, and it is the elderly whose cognition may be affected most in the short term (Comijs, van den Kommer, Minnaar, Penninx, & Deeg, 2011). The degree of the effect on cognition might then depend on the nature of the event, the nature of the individual. In particular, whether there is a cumulative effect of multiple major events may be especially important and seldom assessed.

Comijs et al. (2011) summarised findings of an investigation into the effect that “negative life events” had on the elderly participants in the Longitudinal Aging Study Amsterdam (LASA; <http://www.lasa-vu.nl>), an ongoing population-based prospective cohort study among persons initially aged 55–85 years in the Netherlands (Deeg, Van Tilburg, Smit, & De Leeuw, 2002). The authors used the Mini Mental State Exam (MMSE), albeit a relatively poor tool to measure general cognition and other test neuropsychological tests to measure speed of information processing, and episodic memory. They also looked to assess the effects of “accumulated ... [negative] life events” (pg. 111), including death or illness of a partner, death of a (grand)child, death of a relative, illness, victim of crime, and relocation, in these individuals. Firstly, the accumulated number of life events showed no linear association with cognitive decline, which was the case over all cognitive measures (although each event was evenly weighted and not all events caused significant cognitive changes individually). In terms of life events studied individually, death of a (grand)child, the death of a close relative, illness of the partner, and relocation all had significant associations with changes in cognition. Furthermore, significant interactions with time were found for the death of a (grand)child (lower baseline MMSE and faster decline) and illness of the partner (lower baseline MMSE but slower decline); both interactions stayed significant after adjustment for confounders and depression (Comijs et al., 2011). These changes were based on changes from baseline over the course of testing in the LASA study.

Further to the idea that ‘life events’ can have an effect on cognition, Miller and O’Callaghan (2005) suggest that the combination of aging and stress (and the predicted release of glucocorticoids) may result in accelerated aging of the hippocampus, which is an important part of the limbic system, involved in memory, learning and spatial navigation (Marieb & Hoehn, 2010). They suggest four hypotheses: stress/glucocorticoids accelerates or exacerbates aging; stress/glucocorticoids and aging act in parallel; aging results in excessive stress/glucocorticoids and this enhances vulnerability; all of the effects of aging are due to excessively high levels of stress/glucocorticoids (pg. 131). Irrespective of the mechanism, what is important is that there are forces at work which ultimately result in an accelerated process of aging of the hippocampus in the aging population. By contrast, the current study did not examine the process of accelerated aging, but addresses the novel perspective of potential effects of accumulative significant traumatic events on the cognitive performance in an aged population.

In a more recent study, as part of the Veterans' Affairs Normative Aging Study in the United States, older males were asked to self-report stress they had experienced in the last month, and how they rated its effect on them compared to stress in the past. Those who had rated stress in the last month as being high, performed worse on the MMSE compared to those who had rated stress in the last month as being low (Peters, Weisskopf, Spiro et al., 2009). One might expect a high self-rating of stress would likely mean poor performance on cognitive testing, consistent with the findings reported by Helton et al. (2011) in their assessment of university student's performance after the Canterbury earthquake. The current thesis investigated whether a comparable, and increasing, stress due to the cumulative Canterbury earthquakes had the same effect on multiple measures of cognitive performance, in research that would have been difficult, if not impossible, to adequately plan for on its own.

### **Disasters and the Consequences**

Barton (1969) defined a disaster as a "collective stress experience," in which "large numbers of persons fail to have their usual needs met by the social system" (pg.490, Gibbs, 1989). This section examines specific disasters in the available literature explored for their effects on people subjected to those events. Although the current thesis is concerned with the cognitive consequences of a disaster, the literature tends to focus on the traumatic effects of experiencing a disaster, such as post-traumatic stress disorder (PTSD) and depression. For example, Norris, Friedman, and Watson (2002a), and Norris, Friedman, Watson, Byrne, Diaz and Kaniasty (2002b), provided a comprehensive review of the literature from the previous 20 years that focused on the psychological consequences of both natural and non-natural disasters. Most studies in their review focused on depression and anxiety, and measures of post-traumatic stress, which were indeed common, and although the ways in which these were examined varied significantly, there was an indication that socio-demographic variables were significantly related to the presence of psychological consequences following a disaster.

The demographic variables commonly examined include age, sex and social and economic environment. Of these, the effects of age appear to be the most inconsistent. Several studies have found that older participants experience reduced psychological well-being following natural disasters (Chiu, Hu, Lee, Chen & Hsieh, 2002; Lewin, Carr & Webster, 1998). Knight, Gatz, Heller and Bengtson (2000) were also able to reject the "maturation hypothesis", which states that the oldest participants would be the least reactive

to stress, following the 1994 Northridge earthquake (6.7 on the Richter scale); although the oldest were least likely to ruminate (age did not affect earthquake-specific rumination if there was exposure to damage). The authors were able to support the “inoculation hypothesis”, as those participants with prior exposure to earthquakes in the region experienced lower post-earthquake depression scores. Sex differences have also been investigated, with females reporting greater emotional distress, trauma and mental health problems than men (Fothergill, 1998; Norris et al., 2002b); while a lower socio-economic status is more likely to put added stress on individuals during a disaster due to less quality housing and location (Asgary & Willis, 1997).

In 1999, an earthquake (measuring 7.3 on the Richter scale) struck Taiwan, resulting in 2400 deaths and 100,000 homes destroyed in and around the city of Chi-Chi (Lin, Huang, Huang, Hwang, Tsai & Chiu, 2002). Seplaki, Goldman, Weinstein, and Lin (2006) analysed data from the 1999 wave of the longitudinal Taiwanese Survey of Health and Living Status of the Elderly and the 2000 Social Environment and Biomarkers of Aging Study (SEBAS). Their main interest was pre-earthquake measures of depression and health status (measured by self-report of health, activities of daily living, mobility, medical history and cognition) as well as socioeconomic status (SES) and post-earthquake depression scores and participants experience of the earthquake.

Saplaki et al. (2006) concluded that those who experienced higher levels of depressive symptoms after this Taiwan earthquake were more likely to be of lower SES, socially isolated, and female. Not surprisingly, those who experienced damage to their homes also reported higher levels of depressive symptoms, and those effects were more significant if the participant was aged between 54 and 70. Further, those over the age of 70 fared better than the ‘near-elderly’ (aged 54-70), in terms of depressive symptoms associated with damage to the home; and health status did not appear to have an effect on depressive symptoms post-earthquake. These results suggest that there are factors which may influence how individuals react to a disaster with such damaging consequences. However, this study had several limitations, including the time between the earthquake and the year 2000 interview (up to one year), the small number of variables measured (only depressive symptoms and post-earthquake damage or loss), and the way in which information was gathered (i.e. self-report in some instances). What this study does provide is a justification to continue to examine the effects of disasters, and highlights areas that can be further investigated, to enable targeted care following major events that disrupt our day-to-day lives.

Deeg, Huizink, Comijs and Smid (2005) made use of an ongoing longitudinal study, the LASA, to examine the short-term and long-term health effects of the 1992 airplane crash in a suburb of Amsterdam. They concluded that more negative changes in mobility and general health occurred only in the short term, providing evidence for the value in testing again at a long-term follow-up. The authors also showed that in the short-term, cognitive functioning actually improved before falling back to baseline, adding that stress can have an important impact in improving cognition in the short-term. Overall, the results showed minimal changes in an elderly population. This study provides an example of the resilience of the elderly in the face of a stress-inducing disaster.

Another study that compared the young (<65 years) with the elderly (65 years and older) found that following the 1989 Newcastle earthquake in Australia (measuring 5.6 on the Richter scale), older participants reported fewer threat and disruption experiences and used fewer support services offered, although the elderly experienced more post-traumatic stress symptoms compared to the young (Ticehurst, Webster, Carr and Lewin, 1996). In addition, elderly who experienced more post-traumatic stress symptoms were more affected if female, who used 'behavioural and avoidance coping styles' and reported higher levels of exposure. Ticehurst et al. (1996) concluded that the elderly may in fact fare worse than the young, in terms of post-traumatic stress symptoms, and may not utilise the support services available to them, making them more vulnerable to the long term consequences of experiencing a major stressful event. These results suggest that the elderly are a vulnerable group within the population who warrant further research to determine the effects of a major disaster on their health and well-being.

Not only are the elderly a vulnerable group, albeit variably, within the population during a disaster (Ticehurst et al., 1996), they are of course the most vulnerable to the cognitive decline associated with dementia. The major issue is that there is a significant gap in the literature accurately measuring the effects that a disaster (or major life stressor) has on one's cognition; and those that have claimed to do so, rely on substandard measures of cognitive functioning. For example, Xu and Wu (2011) claimed to analyse "cognitive and psychological consequences among survivors of the Wenchuan earthquake" (pg. 144) at one-year follow-up. However, their definition of cognition was more related to a participant's knowledge and awareness of work and living situations, and how this affected their mental health following the earthquake, making no mention of any reliable measures of cognition.

Further searches of the literature fail to find any specific studies regarding the effect that a disaster has on the cognition of the elderly.

### **Significance of the Current Research**

Due to the paucity of research on the consequences of natural disasters on cognition, and the inability to plan and assess cognition with appropriate measures, the current thesis has considerable significance. Seplaki et al. (2006) summarised several “statistical and methodological limitations that compromise the generalizability of the findings and limit the strength of the resulting inferences from current disaster research” (pg. 3123). One limitation is that many studies are not based on representative samples of a community; many studies are completed following a disaster, so their participants consist of persons seeking medical, psychological or personal assistance. The best way to combat this is through longitudinal research, using data collected before the disaster took place on random, representative samples of the population. Second, most studies have relatively small sample sizes (for example, the median size of the 169 studies reviewed by Norris et al., 2002b, was 149). Third, the lack of longitudinal data specifically relevant to disaster research means there is unlikely to be any comparable assessments completed before the disaster occurs, limiting the ability to analyse the effects of the disaster. Finally, as with the third limitation, there is usually a lack of general health and background information on participants, as well as information regarding participants exposure to the disaster (such as personal loss, damage or objective measures of magnitude of the disaster).

This thesis overcomes these limitations to some extent. First, the data collected through the NZBRI screening study was comprehensive in its ability to detect changes in cognition of the elderly - the initial purpose of the study prior to the initial quake. With more than six hundred participants screened from the general community, recruited from a variety of sources, we can be confident that the sample is reasonably representative of the elderly population in the Canterbury region. Many health and demographic variables were collected and this data will be maintained for use in longitudinal research in the future. Though not specifically designed for measuring the impact of an earthquake, the large scale and broad range of measures used means that this thesis will be able to contribute significantly, not only to disaster research, but also to the study of cognition, the impact of disasters on cognition, and the long term effects and changes.



Irrespective of ‘disaster research’, cognitive changes in the elderly, beyond that of normal aging, are important to monitor, study, and, ideally, prevent. New Zealand faces a sharp rise in the retired population in the near future, and at present, the healthcare system is not prepared for the rise in dementia that will inevitably follow. Wilson, Arnold, Schneider et al. (2006) used clinical and pathological data from the Rush Memory and Aging Project (Bennett, Schneider, Buchman et al., 2005) to assess “chronic psychological distress” and whether this was associated with an increased risk of Alzheimer’s disease. More than six hundred participants (with a mean age of 80.6 years) were assessed on “distress proneness” and then on a battery of twenty cognitive tests with at least one follow-up evaluation during a mean of 2.7 years of observation. If a participant died, an autopsy on their brain was conducted to identify the presence of neuropathological evidence of Alzheimer’s disease. The authors concluded that participants “prone to psychological distress were nearly three times more likely to develop dementia and experienced more rapid decline compared to persons not prone to distress” (pg. 150). Surprisingly, no relationship between distress proneness and Alzheimer’s pathology at autopsy was found, nor was there any mention of the stressors that would cause psychological distress. Thus psychological distress may exacerbate other neuropathology that predisposes to dementia or reduces resilience to Alzheimer pathology.

The above research ties together some important facts, and further demonstrates the complications and complexities of cognition and how it is affected by stress throughout our lives. It may not necessarily be the stressor that causes the typical psychological consequences examined (such as PTSD and depression) but a combination of an individual’s demographic characteristics, social supports, and method of coping, while cognitive changes may also result from “proneness to distress”, and loss, or objective impact of the stress on the individual. Many of these factors are extremely difficult to assess before a disaster occurs, meaning there is a greater importance on longitudinal research in disaster prone areas, where measures are required beyond just what is being assessed, such as those variables just mentioned. Nevertheless, cognition is still extremely important to assess whenever the chance arises, and even more important to learn about the impact that specific stressors may have, especially in those who are most prone to cognitive decline (in this case, the elderly).

The current thesis aimed to test the primary hypothesis that an increasing ‘dose’ of earthquakes would negatively impact on cognition, while controlling for an estimated full scale intelligence quotient (Est-FSIQ), using the New Zealand Brain Research Institute’s

cognition screening data. Further, it was hypothesised that having a significant medical condition would further exacerbate any earthquake effect on the cognition of the elderly. Secondary hypotheses aimed to test whether sex or age (again, controlling for Est-FSIQ), or Est-FSIQ would also further exacerbate an earthquake ‘dose’ effect. In other words, would experiencing an increasing number of earthquakes in the Canterbury region lead to measurable differences in cognitive functioning compared to those who had not experience the earthquakes before testing, and would having a medical condition, being female, older (>73), or having a low (<111) Est-FSIQ promote further cognitive decline on a battery of neuropsychological tests and a self-reported questionnaire. Following this, predicted variable analysis was conducted to further investigate the relationship between the demographic variables and whether an earthquake effect could be predicted based on the large sample available.

## **Method**

### **Participants**

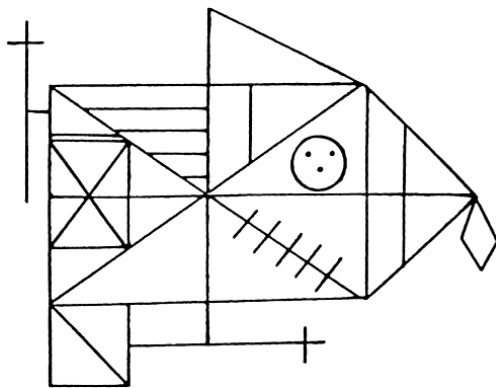
Six hundred and nine participants were screened as part of the New Zealand Brain Institute’s (NZBRI’s) Memory, attention, and language screening study. Participants for this study were recruited from local newspaper articles (The Press and its subsidiary, rural papers), advertisements in targeted older person’s magazines distributed by the national body Age Concern (see Appendix A), NZBRI information talks at community meetings, retirement village visits, directly from the NZBRI volunteer database, referrals from friends, families, and/or word-of-mouth (see Appendix B for Information Sheet). All participants were aged 65 years and older, and there were 18 exclusions due to a diagnosed neurological condition (N = 9), neurosurgery (N = 1), visual/language barrier affecting testing (N = 3), uncompleted tests (N = 4) and alcohol intoxication (N = 1).

### **Procedure and Materials**

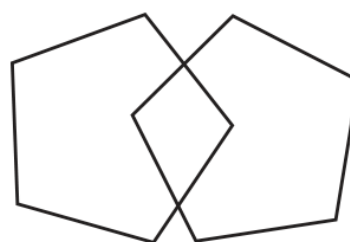
The NZBRI screening study consisted of an interview and neuropsychological testing for about one hour, either at the NZBRI (66 Stewart St, Christchurch) or in the participant’s home if they were unable to travel to the NZBRI. A list of any current medications, occupation, years of formal education, alcohol use, personal, contact and health checklist (Appendix C) were previously obtained by phone interview (usually conducted by study

coordinator, Leslie Livingston). A consent form was also signed at the start of the scheduled interview (Appendix D) with an ethnicity question. Interviewers consisted of postgraduate students and research assistant volunteers, recruited from the University of Canterbury. For consistency, each interviewer was trained in the same way, followed the same script and used the same materials for each assessment; for volunteers, debriefing occurred after each assessment with one or more members of the research team.

The neuropsychological tests and their order were as follows: The Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005); Rey Complex Figure (copy and immediate [3-min] recall, with the delay filled by a brief discussion; Rey, 1941; Gasparini et al., 2008); see Figure 1A; further, the Kixmiller system was then used to score the planning of Rey Copy); Trail Making Test A (Reitan, 1958); the Mini-Mental State Examination pentagon drawing (Figure 1B; Folstein, Folstein & McHugh, 1975); and the AD8 (a brief, self-report questionnaire used to self-rate everyday function; Galvin et al., 2005. See Appendix E). At the end of testing a short recording of the participant's voice was made using a Zoom H4n Handy Recorder voice recorder, for which participants answered a few questions (see script, Appendix F), and read a short passage (The Grandfather Passage, Appendix G). After the 13<sup>th</sup> June 2011 earthquake, the Geriatric Depression Scale (Yesavage et al., 1983) and the Geriatric Anxiety Inventory (Pachana et al., 2007) were added to the end of the interview.



**Figure 1A** Rey Complex Figure



**Figure 1B** MMSE Pentagon Drawing

### **Description of Groups**

Four EQ-dose groups were defined, based on relative number of exposures to major quake events when they received neuropsychological testing. “EQ-dose: None”, referred to the group of participants who participated in the study between its commencement prior to the

first major earthquake that affected the Canterbury region, on September 4<sup>th</sup>, 2010 (N = 51); “EQ-dose: One”, included those who participated in the study between the September 4<sup>th</sup> earthquake and prior to the second (and more devastating) major earthquake to affect the region on the 22<sup>nd</sup> of February, 2011 (N = 193); “EQ-dose: Two”, included those who had experienced the two major earthquakes prior to the third major earthquake to hit the region on June 13<sup>th</sup>, 2011 (N = 82); finally, “EQ-dose: Three”, consisted of participants who participated after the third major earthquake on June 14<sup>th</sup>, 2011 (N = 265), who had thus experienced all three major Canterbury earthquakes before undertaking neuropsychological testing. All participants bar those in “EQ-dose: None” also experienced the continuous aftershocks and minor earthquakes in their respective periods, this being the greatest for “EQ-dose: Three”.

In addition, some participants were sub-classified as being in a Medical group (N = 157) consisting of participants who reported having suffered from a previous and ongoing medical condition that may in some way affect their current health, well-being, or cognitive functioning which included, but was not limited to, cardiovascular disease, chronic health conditions (e.g. cancer, diabetes, smoking-related-illnesses), major surgery, psychiatric illness, head trauma and neurological conditions (e.g. epilepsy, stroke, multiple transient ischaemic attacks, multiple sclerosis), or had alcohol and other drug abuse (see Appendix C). The Non-Medical group (N = 434) was made up of participants who did not report any of the above, or who had sufficiently recovered from any of the above over an extended time period, which was at the researcher’s discretion.

## **Data Analysis**

### **Power Analysis**

The current study was opportunistic, given the unpredictable nature of the natural disaster, so the sample sizes of the four groups were unplanned. Hence an important concern is whether the samples obtained provided sufficient statistical power to detect relevant effect sizes. The harmonic mean sample size of the four EQ-dose groups was 98 (“EQ-dose: None”, N = 51; “EQ-dose: One”, N = 193; “EQ-dose: Two”, N = 82; “EQ-dose: Three”, N = 265) and this ‘N’ was used to evaluate statistical power using Power and Precision (Version 2; Biostat, 2000). The study had sufficient power to detect meaningful differences across the four groups, because it had 81% power at  $\alpha = 0.05$  to detect an analysis of covariance

(ANCOVA) effect size (with one covariate) of  $f = 0.17$  (i.e. a small to medium effect size across the four groups). A small to medium effect on cognition would be of practical importance and is concluded that the current study was sufficiently powered to detect a relevant main effect of EQ-dose group should any exist. The statistical power for a medium effect size ( $f = 0.25$ ) was almost maximal (99%). The  $f = 0.17$  effect size could be equivalent to the following scenario of standardised mean pairwise group differences such as: a small effect between “EQ-dose: None” (standardized mean = 0.0) and “EQ-dose: One” (standardized mean = 0.20; i.e. 0.2 SD different to EQ-dose: None) and “EQ-dose: One” and “EQ-dose: Two”, plus a standardised mean difference between “EQ-dose: Two” and “EQ-dose: Three” equal to 0.40 (a standardized difference of 0.5 is regarded as a medium effect size). A more graduated effect across groups (with the corresponding standardized means: 0.0, 0.2, 0.3, 0.4 for the four groups relative to “EQ-dose: None” at 0.0) generates an effect size,  $f = 0.15$ .

### **Group Analysis**

The primary analysis used a four (EQ-dose group) by two (Medical Condition: Major medical issue vs Minor/none) design. Differences for demographic variables between the four EQ-dose groups (None, and One, Two or Three major seismic events) were analysed using analysis of variance (ANOVA). As there were insufficient numbers in some cells and unbalanced cell frequencies for a three-way ANOVA when Sex was added (e.g. minimum cell size of  $N = 3$  vs. maximum  $N = 118$ , as opposed to minimum cell size of  $N = 12$  vs. maximum  $N = 191$  without Sex), instead Sex replaced Medical Condition as a factor in a separate ANOVA. Another question was whether age of the participant had any influence on the EQ-dose effect. A median split for age across the whole sample (younger,  $<74$ yr, vs. older,  $>73$ yr) was used in place of Medical Condition and Sex in a third analysis, but now with Estimated Full Scale Intelligence Quotient (Est-FSIQ) as a covariate. As some dependent variables showed non-normal distributions (visual inspection of the P-P plot and Kolmogorov-Smirnov Test statistic), the primary EQ group variable in those instances was re-examined using one-way Kruskal-Wallis tests.

The primary interest concerned differences on raw or normed (Z-scored) neuropsychological variables between the four EQ-dose groups, which were analysed in a similar fashion, except that Est-FSIQ was used as a covariate (ANCOVA). Rey Copy, Rey Immediate (3min) Recall and Trail A raw scores were standardised based on z-transformation

using the whole group so as to emphasise valid comparisons within this sample as a means of expressing potential EQ-dose effects. The rationale for using Est-FSIQ was to avoid any confound of the effect of different IQs on the EQ-dose effect. The Est-FSIQ was derived from key measures of age, education and occupation rating using the formula  $Est-FSIQ = 87.14 - (5.21 \times occupation) + (1.78 \times years\ of\ education) + (0.18 \times age)$  (Crawford, Millar & Milne, 2001), where occupation codes (Table 1) were derived from “social class codings” from Table 1 in Crawford, Allan, Cochrane and Parker (1990). To examine explicitly the potential influence of Est-FSIQ on an EQ-dose effect, a median split of Est-FSIQ across the whole sample was used to generate high (>111) vs low (< 111) Est-FSIQ groups and entered into an ANOVA in place of Medical Condition or Sex to avoid problems with insufficient number or empty cells in the analysis. As with the analysis of demographics, neuropsychological variables showing non-normal distributions were re-examined using one-way Kruskal-Wallis tests for EQ-dose groups.

**Table 1** Occupation codings copied from Table 1 in Crawford, Allan, Cochrane and Parker (1990), pg. 436

1 (Professional)	Architect; chartered accountant; dentist; doctor; economist; lawyer; lecturer; pilot; church minister
2 (Intermediate)	Computer programmer; real estate agent; librarian; manager- advertising, public relations, purchasing, marketing; nurse; social worker; teacher
3 (Skilled)	Carpenter; chef; clerk; driver- bus, lorry, train; electrician; fire(wo)man; hairdresser; plumber; police(wo)man; salesperson; secretary; telephone operator; toolmaker
4 (Semi-skilled)	Assembly line worker; barperson; fisher(wo)man; glazier; hospital porter; storekeeper; telephone receptionist; traffic warden; waiter
5 (Unskilled)	Cleaner; docker; kitchen porter; labourer; refuse collector; sewage worker

None of the neuropsychological tests had been normed within New Zealand in this age group. As the overall sample was moderately large, this problem was addressed by supplementary analyses using multiple regression. That is, the sample itself was used to generate predicted scores for each dependent variable based on age, sex and Est-FSIQ. These statistically predicted scores were then normed within the group to generated sample-specific

Z-scores. In this way, the relative effects across the four groups would be more relevant than converting scores to (sometimes) less reliable standard scores. The same analyses as described earlier were then conducted.

## Results

### Demographic Comparisons

Table 2 summarises the demographic characteristics of each of the four EQ-dose conditions and for each Medical Condition subgroup. Education was the only demographic variable to show a significant effect of EQ-dose,  $F(3,587) = 4.36$ ,  $p = 0.005$ . Tukey HSD Post Hoc Tests ( $p < 0.05$ ) confirmed that participants in “EQ-dose: Three”, had significantly higher years of education than EQ-dose groups None and Two, but not “EQ-dose: One”, ( $p < 0.05$ ). Other independent variables measured were alcohol consumption and ethnicity, both of which showed no significant effect of EQ-dose or Medical condition. In terms of age, participants with a major medical condition were significantly older ( $M = 75.6$ ,  $SD = 6.26$ ) than participants with a minor or no medical condition ( $M = 73.4$ ,  $SD = 5.98$ ),  $F(1,583) = 9.24$ ,  $p = 0.002$ . No other effects or interactions were found to be significant.

Age differences were then examined by two-way ANOVA with EQ-dose group as the primary factor, but now when age was simply divided into ‘Younger’ (<74) vs. ‘Older’ (>73) groups based on a median split of the age data from all five hundred and ninety one participants it enabled an analysis that included Sex. Male participants were significantly older than females in EQ-dose groups None, One and Two,  $F(1,583) = 10.08$ ,  $p = 0.002$ , but this difference was reduced in EQ-dose: Three, as supported by a significant interaction of EQ-dose group\*Age\*Sex,  $F(3,583) = 2.82$ ,  $p = 0.038$ . Comparing sex differences, males had significantly higher estimated premorbid full scale IQ (Est-FSIQ) than females,  $F(1,583) = 28.1$ ,  $p < 0.001$ , presumably reflecting greater access to education and occupation in this age group in New Zealand. Also, as would be predicted, participants with a High Est-FSIQ (>111; based on a median split of all participants) had received far more years of education than participants with a Low Est-FSIQ (<111),  $F(1,583) = 338.1$ ,  $p < 0.0001$ .

**Table 2** Demographic characteristics for the study sample (N = 591)

	EQ-dose: None				EQ-dose: One				EQ-dose: Two				EQ-dose: Three										
	Non-Medical		Medical		EQ		Non-Medical		Medical		EQ		Non-Medical		Medical		EQ						
Sex	M	F	M	F	Mean ± SD		M	F	M	F	Mean ± SD		M	F	M	F	Mean ± SD						
N	11	28	3	9	51		50	91	22	30	193		24	39	6	13	82		73	118	24	50	265
Age	75.2 ± 6.1	73.3 ± 6.5	82.7 ± 7.0	73.3 ± 5.1	74.3 ± 6.4		74.9 ± 6.5	73.3 ± 6.4	77.5 ± 6.9	73.1 ± 6.2	74.2 ± 6.5		75.0 ± 5.1	73.0 ± 5.0	80.3 ± 4.6	74.8 ± 5.8	74.4 ± 5.4		73.6 ± 5.6	72.6 ± 6.0	74.3 ± 5.3	76.7 ± 6.1	73.8 ± 6.0
(Yrs)																							
Ed	13.1 ± 2.6	11.8 ± 2.2	14.0 ± 5.3	11.2 ± 1.8	12.1 ± 2.5		13.6 ± 3.1	12.6 ± 2.2	12.5 ± 1.7	13.4 ± 2.4	13.0 ± 2.5		13.0 ± 2.6	12.4 ± 2.0	11.2 ± 2.6	12.2 ± 2.4	12.4 ± 2.3		14.5 ± 3.2	12.9 ± 2.4	14.1 ± 3.2	12.2 ± 2.0	13.3 ± 2.8
(Yrs)																							
FSIQ	114.0 ± 11.7	107.2 ± 9.0	116.5 ± 12.7	104.7 ± 7.1	108.8 ± 10.0		113.0 ± 10.4	108.1 ± 8.9	110.8 ± 5.4	110.7 ± 9.3	110.1 ± 9.2		111.0 ± 7.9	108.5 ± 7.8	107.6 ± 11.3	107.2 ± 9.2	108.9 ± 8.3		113.8 ± 9.0	109.2 ± 8.7	114.3 ± 10.3	106.8 ± 8.4	111.0 ± 9.5



Because the variables of Age and Education did not follow a normal distribution (skewness coefficient = 0.547,  $p < 0.0001$ , and 0.708,  $p < 0.0001$ , respectively), a Kruskal-Wallis one-way ANOVA was conducted. Corrected for ties, the variables of Age and Education returned results consistent with the ANOVAs, with Age showing a no significant differences between EQ-dose condition, while there was a statistically significant difference between EQ-dose groups for Education as reported above with  $H(3) = 1.17$ ,  $p = 0.761$  and  $H(3) = 11.0$ ,  $p = 0.012$ , respectively. Normality was accepted for Est-FSIQ (Kolmogorov-Smirnov test for normal distribution,  $p = 0.280$ ).

### **Neuropsychological Testing**

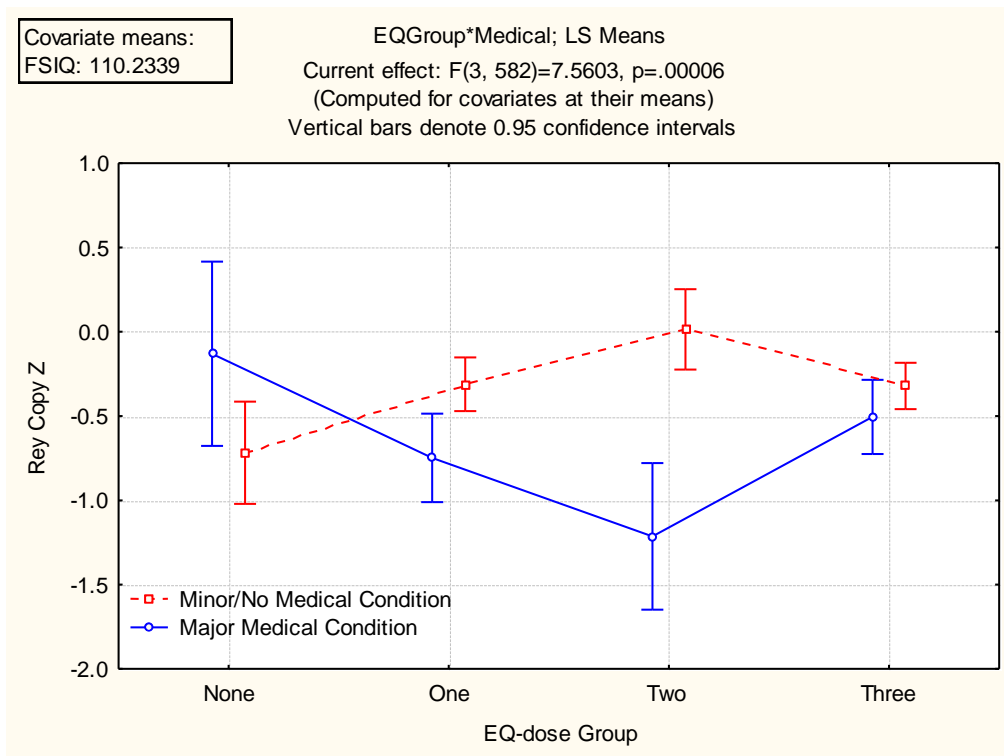
Differences in neuropsychological scores represented the main aim of this thesis. Table 3 summarises the analysis for the neuropsychological variables using a four (EQ-dose) by two (Medical Condition) ANCOVA with Est-FSIQ used as the covariate. This analysis addresses the question whether quantity and overall duration or exposure to major seismic events have a significant effect on neuropsychological performance and whether any such effect depends on an existing medical condition or not, once the influence of Est-FSIQ is controlled. Table 3 summarises means and F-values of all of the neuropsychological tests by EQ-dose and Medical Condition. Of the seven measures, only Trials A ( $p < 0.023$ ) and AD8 ( $p < 0.003$ ) showed a significant EQ-dose main effect.

Having a major medical condition had a significant (detrimental) effect on measures including the MoCA-ed ( $p < 0.0006$ ), Rey Copy ( $p < 0.006$ ), Rey 3min ( $p < 0.009$ ), Trail A ( $p < 0.028$ ), and AD8 ( $p < 0.018$ ), but not Rey Planning ( $p = 0.07$ ) and the Pentagons task ( $p = 0.346$ ). There was also an interaction of EQ-dose and Medical Condition on Rey Copy ( $p < 0.00006$ ) and a further interaction on Rey intermediate (three minute) recall ( $p < 0.017$ ). Figure 2 displays the interaction, where those with a major medical condition declined in performance on the Rey Copy at “EQ-dose: Two”, while those with no medical condition improved. Figure 3 shows a similar pattern on the Rey Immediate (3min) Recall: where those with a major medical condition declined in scores to “EQ-dose: Two”, while those with no medical condition improved.

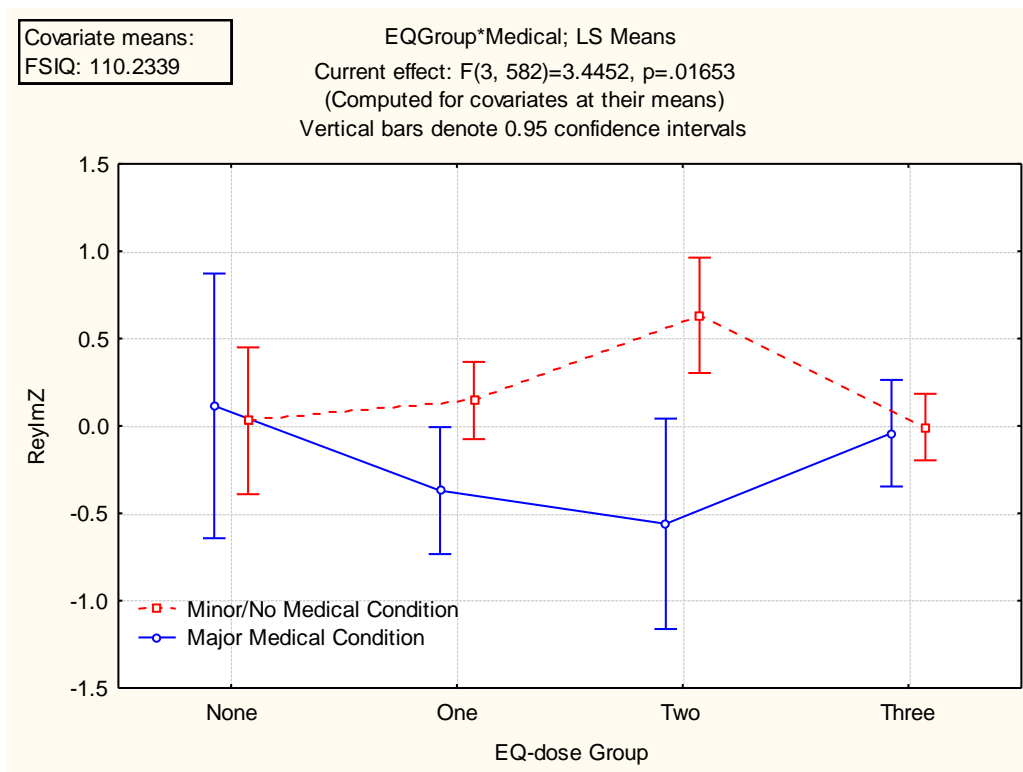
**Table 3** Means and F-values of neuropsychological tests by EQ-dose and Medical Condition

		EQ-dose: None		EQ-dose: One		EQ-dose: Two		EQ-dose: Three		EQ- dose <i>F</i>	Medical Condition <i>F</i>	EQ x MC <i>F</i>
NP	MC	None	Major	None	Major	None	Major	None	Major			
	MoCA-ed	25.87	25.25	26.31	24.88	26.24	24.21	25.83	25.05	0.22	12.00**	1.14
	Rey Copy	-0.74	-0.18	-0.32	-0.74	0.00	-1.27	-0.29	-0.52	0.82	7.68*	7.56**
	Rey 3min	0.00	0.04	0.13	-0.36	0.61	-0.64	0.04	-0.07	0.31	6.92*	3.45*
	Rey Plan	5.95	6.33	6.06	5.52	6.10	5.21	6.03	5.53	0.81	3.28	1.21
	Trail A	0.63	0.25	0.58	0.11	0.50	0.65	0.67	0.54	3.20*	4.87*	2.27
	Pentagons	9.85	9.73	9.76	9.65	9.70	9.58	9.73	9.77	0.67	0.89	0.87
	AD8	1.26	1.36	1.21	1.54	1.10	1.47	1.41	2.27	4.82*	5.66*	1.36

MC = Medical Condition; NP = Neuropsychological Test; \* =  $p < 0.05$ ; \*\* =  $p < 0.001$



**Figure 2** Rey Copy Z score interaction effect of EQ-dose\*Medical condition



**Figure 3** Rey Immediate (3min) Recall Z score interaction effect of EQ-dose\*Medical condition

Table 4 summarises a further analysis of the dependent variables from the four (EQ-dose) conditions when analysed to look at the potential impact of Sex, in an ANCOVA with Est-FSIQ as the covariate. The only significant EQ-dose effect in this analysis was on the AD8 measure ( $p < 0.012$ ); significant main effects of Sex were found for the MoCA (adjusted for education;  $p < 0.001$ ), Rey Plan ( $p < 0.003$ ) and Trail A ( $p < 0.016$ ) with males performing better on Trail A and Rey planning. There were no significant interactions.

**Table 4** Means and F-values of neuropsychological tests by EQ-dose and Sex

		EQ-dose: None		EQ-dose: One		EQ-dose: Two		EQ-dose: Three		EQ-dose <i>F</i>	Sex <i>F</i>	EQ x Sex <i>F</i>
NP	Sex	Male	Female	Male	Female	Male	Female	Male	Female			
	MoCA-ed	24.79	26.08	25.36	26.26	25.80	25.75	25.10	25.91	0.90	11.00**	1.04
	Rey Copy	-0.10	-0.80	-0.35	-0.48	-0.12	-0.40	-0.33	-0.38	0.71	2.88	1.45
	Rey 3min	0.19	-0.06	0.23	-0.13	0.76	0.06	0.19	-0.10	2.16	2.97	0.86
	Rey Plan	6.71	5.78	6.39	5.63	6.13	5.75	6.25	5.68	0.46	8.86*	0.39
	Trail A	0.29	0.62	0.27	0.56	0.41	0.61	0.53	0.69	2.11	5.80*	0.33
	Pentagons	10.0	9.75	9.75	9.72	9.70	9.65	9.79	9.71	0.95	0.69	0.27
	AD8	1.64	1.14	1.40	1.23	1.13	1.21	1.72	1.61	3.70*	2.52	0.47

\* =  $p < 0.05$ ; \*\* =  $p < 0.001$

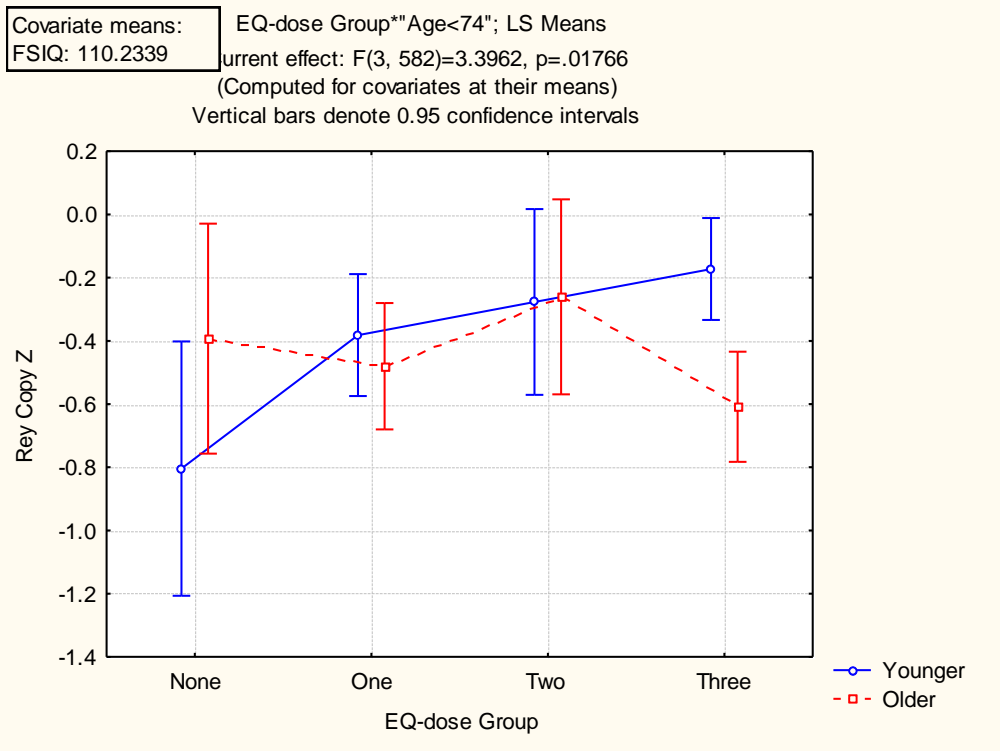
Young (<74 years) participants were compared to older (>73 years) participants (Table 5) in a separate four (EQ-dose) by two (Age) ANCOVA, with Est-FSIQ again used as the covariate. Again, in this analysis, AD8 shows a significant EQ-dose effect ( $p < 0.007$ ), while the only age effect was on the MoCA (education adjusted), with younger participants having a significantly higher MoCA score than older participants ( $p < 0.0001$ ).

**Table 5** Means and F-values of neuropsychological tests by EQ-dose and Age

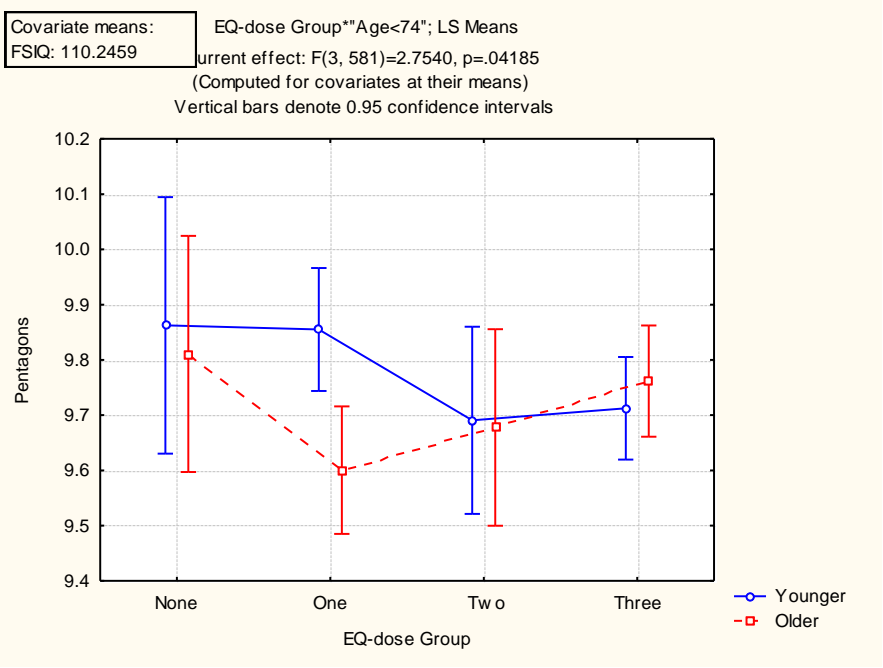
		EQ-dose: None		EQ-dose: One		EQ-dose: Two		EQ-dose: Three		EQ- dose <i>F</i>	Age <i>F</i>	EQ x Age <i>F</i>
NP	Age	Young	Older	Young	Older	Young	Older	Young	Older			
	MoCA-ed	26.35	25.21	26.84	24.95	26.65	24.79	26.32	24.79	0.82	36.55**	0.41
	Rey Copy	-0.87	-0.39	-0.41	-0.46	-0.31	-0.28	-0.16	-0.59	1.25	0.07	3.40*
	Rey 3min	0.12	-0.09	0.03	-0.03	0.23	0.42	0.06	-0.06	1.77	0.50	0.42
	Rey Plan	6.00	6.07	6.20	5.60	5.88	5.90	6.11	5.63	0.34	3.38	1.12
	Trail A	0.70	0.40	0.57	0.33	0.45	0.63	0.67	0.58	1.83	1.41	1.36
	Pentagons	9.83	9.81	9.84	9.61	9.67	9.67	9.72	9.77	0.77	1.37	2.75*
	AD8	1.00	1.52	1.35	1.24	1.05	1.33	1.50	1.83	4.13*	3.53	1.08

NP = Neuropsychological Test; \* =  $p < 0.05$ ; \*\* =  $p < 0.001$

This EQ-dose Group by Age Group analysis across the neuropsychological variables revealed two interaction effects, for Rey Copy and the Pentagon drawings. For Rey Copy Z scores, Figure 4 shows that younger participants in “EQ-dose: None” performed worse than older participants in the same EQ-dose group, whereas the opposite was evident for “EQ-dose: Three”. For Pentagons, Figure 5 indicates that the older participants performed worse in “EQ-dose: One”, compared to their younger counterparts.



**Figure 4** Rey Copy Z score interaction effect of EQ-dose\*Age



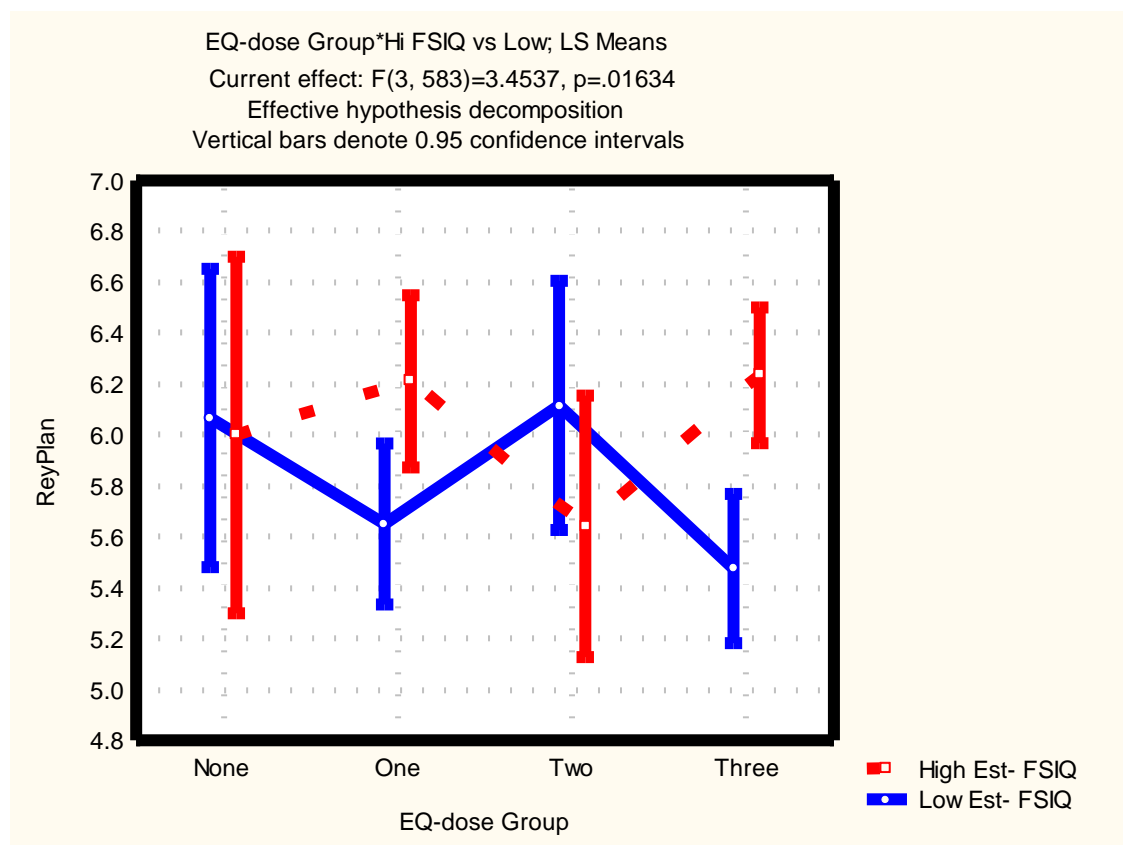
**Figure 5** Pentagon drawing interaction effect of EQ-dose\*Age

Finally, a median split of Est-FSIQ was used to determine whether higher vs lower premorbid IQ had any influence on the EQ-dose effect. Table 6 summarises dependent variables analysed in the series of four (EQ-dose effect) by two (Est-FSIQ) ANOVAs, where ‘high’ Est-FSIQ > 111 and ‘low’ Est-FSIQ < 111. Only the AD8 measure showed a significant EQ-dose effect ( $p < 0.011$ ), while there was a significant effect of Est-FSIQ for MoCA (education adjusted;  $p < 0.008$ ) and Rey intermediate (three minute) recall ( $p < 0.016$ ), with participants with higher Est-FSIQ performed significantly better than participants with a low Est-FSIQ. Figure 6 indicates the one interaction, a difference in Rey Planning scores at “EQ-dose: Three”, where low Est-FSIQ declined significantly compared to high Est-FSIQ ( $p < 0.016$ ), while there were no differences at each of the other EQ-dose groups.

**Table 6** Means and F-values of neuropsychological tests by EQ-dose and Est-FSIQ

		EQ-dose: None		EQ-dose: One		EQ-dose: Two		EQ-dose: Three		EQ- dose <i>F</i>	Est-FSIQ <i>F</i>	EQ x FSIQ <i>F</i>
NP	FSIQ	High	Low	High	Low	High	Low	High	Low			
	MoCA-ed	26.10	25.47	26.23	25.66	26.15	25.42	26.16	24.96	0.69	7.18*	0.50
	Rey Copy	-0.57	-0.64	-0.27	-0.58	-0.30	-0.30	-0.19	-0.56	1.06	3.33	0.88
	Rey 3min	0.33	-0.22	0.25	-0.21	0.28	0.36	0.19	-0.22	1.27	5.82*	0.90
	Rey Plan	6.00	6.07	6.21	5.65	5.64	6.12	6.23	5.48	0.20	1.37	3.45*
	Trail A	0.40	0.62	0.39	0.51	0.60	0.48	0.58	0.69	1.90	0.93	0.57
	Pentagons	9.86	9.79	9.79	9.68	9.74	9.60	9.81	9.67	0.70	3.70	0.10
	AD8	1.29	1.28	1.09	1.48	1.10	1.26	1.57	1.74	3.78*	1.39	0.35

\* =  $p < 0.05$



**Figure 6** Rey Planning interaction effect of EQ-dose\*Est-FSIQ

### Dependent Variable Analysis: Krsukal-Wallis

The dependent neuropsychological test variables MoCA-Ed, Rey Copy, Rey Plan, Trail A, Pentagons and the AD8 displayed some form of skewness that lead to the rejection of normality (skewness coefficients respectively: -0.91, -0.95, -0.43, -1.75, -2.76, and 1.08). Rey 3min Recall maintained a normal distribution (Kolmogorov-Smirnov test for Normal distribution,  $p = 0.0883$ ). The six non-normally distributed variables were re-examined using one-way Kruskal-Wallis tests for EQ-dose groups. Table 7 summarises the test statistics which shows no significant differences for MoCA-ed, Rey Copy, Rey Plan, Trail A and Pentagons. AD8, however, is the only variable which returned a significant result; this is in contrast to the above analyses as there is no longer a significant effect of EQ-dose group for Trail A, while AD8 is the only variable that is consistent for an EQ-dose effect. Table 8 summarises the Tukey HSD Post Hoc analysis for AD8 for each EQ-dose group which shows that EQ-dose: Three is significantly different to both EQ-dose: One and



EQ-dose: Two, while there is no significant differences between EQ-dose: None and the other three factors.

**Table 7** Neuropsychological variables in a one-way Kruskal-Wallis test over EQ-dose group

	Test Statistic	Corrected for Ties (Ht)	Significance Level
MoCA-ed	3.95	4.01	0.15
Rey Copy	5.26	5.26	0.15
Rey Plan	0.32	0.33	0.95
Trail A	5.29	5.29	0.15
Pentagons	1.50	2.93	0.40
AD8	8.43	9.03	0.03*

\* =  $p < 0.05$

**Table 8** Tukey HSD Post Hoc Test for the dependent variable AD8, over EQ-dose group

EQ-dose: Group	n	Average Rank	Different (P<0.05) from factor nr
(1) None	50	282.40	
(2) One	193	280.17	(4)
(3) Two	82	268.10	(4)
(4) Three	265	317.62	(2)(3)

### Sample Generated, Normative Data Based on Age, Sex and Est-FSIQ

Regression analysis was then performed using MedCalc for Windows, version 12.5 (MedCalc Software, Ostend, Belgium). Each independent variable was entered into the regression equation for each dependent variable in a single step, regardless of whether they were significant. Predicted scores for each variable were then normed within the group, generating sample-specific Z-scores. The above analyses were repeated as ANOVAs, the primary analysis was a 4 (EQ-dose Group) by 2 (Medical Condition) design.

Table 9 summarises the F-values for the predicted-score analyses of the four (EQ-dose) by two (Medical Condition) ANOVA. Based on the within-group generated samples, no effect was seen as a result of the significant seismic events that occurred throughout cognitive screening. However, a significant effect of medical condition can be seen for every neuropsychological test ( $p < 0.05$ ), with a large effect observed for Rey 3min ( $p < 0.001$ ), an important test of short term memory. Importantly, when controlling for the dependent variables, there was no longer a significant interaction for any of the dependent variables.

**Table 9** Predicted Variable Analysis: Four (EQ-dose) by Two (Medical condition) ANOVA F values

NP	EQ-dose F	MC F	EQ x MC F
MoCA-ed	0.96	8.97*	1.20
Rey Copy	0.66	10.04*	1.13
Rey 3min	1.03	11.13**	1.92
Rey Plan	1.37	7.09*	2.18
Trail A	0.50	9.85*	0.91
Pentagons	1.41	4.12*	1.79
AD8	0.85	6.45*	0.83

NP = Neuropsychological variables; MC = Medical Condition; \* =  $p < 0.05$ ; \*\* =  $p < 0.001$

Table 10 summarises the predicted variable analysis of a four (EQ-dose) by two (Sex) ANOVA and indicates that years of education has influenced the predicted scores for Sex, as males in EQ-dose: Three had significantly higher education than any other sub-group. Therefore, their predicted score increased significantly post-June (or EQ-dose: Three) and as a result there is a significant EQ-dose effect for four of the dependent variables (MoCA-ed, Rey Plan, Pentagons and AD8;  $p < 0.05$ ) and an interaction effect (EQ-dose\*Sex;  $p < 0.05$ ) for all measures aside from Rey Copy. Females had significantly higher scores on the MoCA ( $p < 0.001$ ) and Trail A ( $p < 0.05$ ), while males had significantly higher scores on the Rey Copy ( $p < 0.05$ ), Rey 3min ( $p < 0.001$ ), Rey Plan ( $p < 0.001$ ), and Pentagons ( $p < 0.001$ ). Males also scored significantly higher on the AD8 for ‘dementia-related’ complaints ( $p < 0.001$ ).

**Table 10** Predicted Variable Analysis: Four (EQ-dose) by Two (Sex) ANOVA F values

NP	EQ-dose F	Sex F	EQ x Sex F
MoCA-ed	2.79*	27.66**	3.79*
Rey Copy	1.27	10.75*	2.21
Rey 3min	2.17	14.81**	3.38*
Rey Plan	2.73*	249.89**	3.76*
Trail A	1.72	47.58*	2.91*
Pentagons	2.87*	39.92**	3.30*
AD8	2.92*	76.01**	3.83*

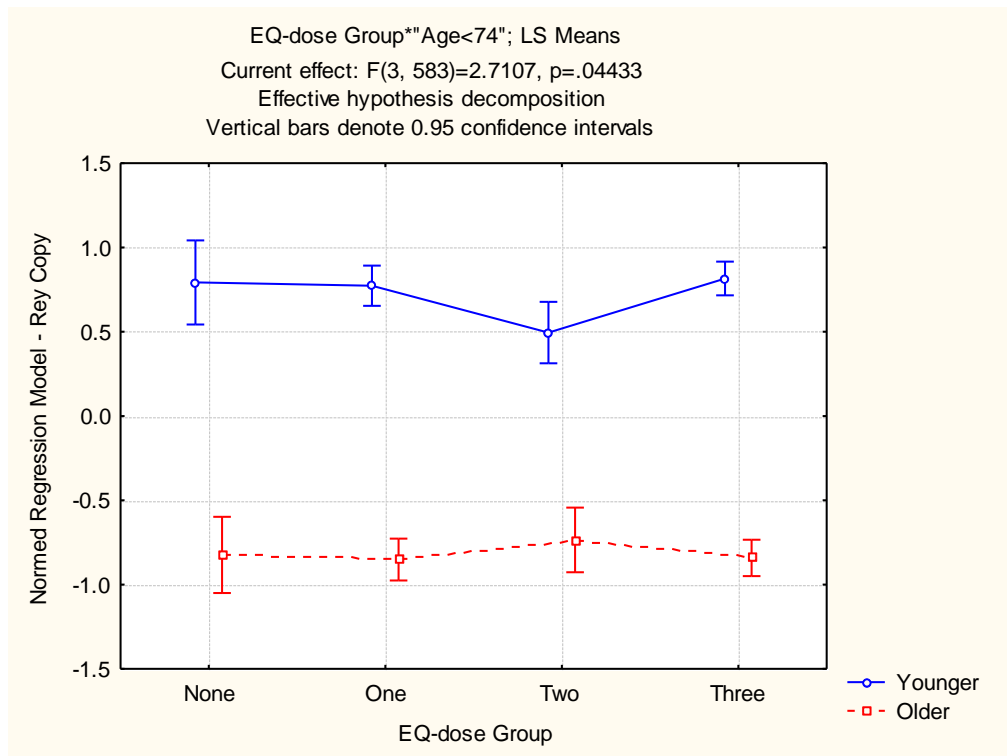
\* =  $p < 0.05$ ; \*\* =  $p < 0.001$

Finally, Table 11 summarises the predicted variable analysis of a four (EQ-dose) by two (Age) ANOVA, and as with sex, age was also a significant predictor, with a large effect observed for every neuropsychological test ( $p < 0.001$ ). In other words, being over 73 years of age was a significant predictor of poorer performance on each of the neuropsychological measures; however, there was no significant effect of EQ-dose on any of the measures assessed. A significant interaction between Age and EQ-dose group was also observed for Rey Copy ( $p < 0.05$ ) as presented in Figure 7: although there was a significant age effect, from “EQ-dose: Two”, older participants declined further, while younger participants scores increased by “EQ-dose: Three” on the Rey Copy.

**Table 11** Predicted Variable Analysis: Four (EQ-dose) by Two (Age) ANOVA F values

NP	EQ-dose F	Age F	EQ x Age F
MoCA-ed	1.52	245.55**	0.22
Rey Copy	0.67	617.96**	2.71*
Rey 3min	1.02	329.46**	1.27
Rey Plan	1.05	61.97**	2.09
Trail A	1.52	577.57**	1.43
Pentagons	1.61	12.11**	0.98
AD8	1.43	167.06**	0.25

\* =  $p < 0.05$ ; \*\* =  $p < 0.001$



**Figure 7** Normed regression model: Rey Copy interaction for EQ-dose\*Age

## Discussion

### General Findings

Studying the effects of disasters on a population usually focuses on psychiatric measures such as depression and anxiety, rather than cognition (Norris et al., 2002a & 2002b). The methodology by which this is achieved is usually substandard; participants are often not representative of the general population, studies have small sample sizes, lack longitudinal data and lack appropriate, relevant background variables of participants (Seplaki et al., 2006). In addition, the potential impact of disasters on the elderly, and especially an ongoing major disaster, it seems, has never been addressed. This thesis countered many of the well-known limitations that limit the effectiveness of disaster research. Six hundred and nine participants were interviewed and tested on a short screen of specific neuropsychological measures over the course of a year, during which time the Canterbury region in New Zealand experienced some of the most violent and destructive earthquakes ever recorded (Lin et al., 2011). This New Zealand study was maximally powered (99%) if a main effect of EQ-dose was present due to a medium effect size,  $f = 0.25$  (with  $\alpha = 0.05$ ). Five hypotheses were examined by

measuring cognition on a battery of neuropsychological tests aimed at identifying cognitive status in participants aged sixty five years and over from the Canterbury region.

The main hypothesis the current thesis was whether there would be an earthquake-dose effect. That is, would there be a decrease in neuropsychological test scores as the number of major seismic events increased, compared to scores from participants who had been tested before the earthquakes started. The results suggest that there was a significant EQ-dose effect on two measures, including the Trail Making Test A and the AD8, a brief dementia screening tool. Trail A has been hypothesised to test attention, visual search and scanning, sequencing and shifting, psychomotor speed, abstraction, flexibility, ability to execute and modify a plan of action, and ability to maintain two trains of thought simultaneously (Salthouse, 2011). The AD8 is a screen of everyday cognition that is expected to differentiate non-demented from demented individuals, although “the utility was better in mildly impaired individuals compared with more demented individuals” (Galvin et al., 2007).

Older participants with a major medical condition, relative to those with no or only minor medical conditions, performed more poorly on the MoCA (a well-established test of general cognitive status; Nasreddine et al., 2005), Rey Copy and Rey Immediate (3min) Recall (visuospatial constructional ability and visual memory; Rey, 1941), Trail A and the AD8. However, on the Rey Copy and Rey Recall, having one or more major medical conditions was associated with poorer performance after the second major (most significant) earthquake, but was equal that of the non-medical condition by the third major earthquake. This suggests that the second and most devastating quake impaired performance in the more vulnerable, medically-compromised group. Given the cross-sectional nature of the study, it is impossible to be sure of this effect, because the non-medically compromised older group, if anything, tended to perform slightly better on the Rey test at this point in time.

The next hypothesis tested whether sex would interact with an EQ-dose effect, but no such interactions were found. Analyses indicated that only the AD8 showed a significant earthquake effect, while females benefited from having significantly less years of education, and therefore, a one point addition to the MoCA (a significant sex effect), while males performed better on the Trail A and Rey Planning (also significant sex effects). No interactions or other effects were found. Age was also examined in a similar fashion; while the only age effect was for the MoCA (with younger participants scoring significantly higher than older participants), there was a significant interaction with EQ-dose on the Rey Copy,

with older participants performing comparably to younger participants until the final major earthquake, where their scores declined significantly compared to the ‘young’, possibly indicating an accumulated effect of experiencing the most number of earthquakes at testing. Another interaction occurred with the pentagon drawings where the older participants were comparable to the ‘young’ at each EQ-dose apart from after the first major earthquake where their scores were significantly impacted negatively, compared to younger participants.

The final hypothesis examined whether estimated FSIQ had an influence on an EQ-dose effect. Again, AD8 showed a significant EQ-dose effect, while the MoCA and Rey Immediate (3min) Recall showed a significant effect of Est-FSIQ, with an FSIQ greater than 111 performing better than an Est-FSIQ of less than 111. It also appeared that having a lower Est-FSIQ was associated with reduced function on Rey Planning if participants had experienced the first major earthquake, and if they had experienced all three of the major earthquakes, compared to those with a higher Est-FSIQ.

In analysing the dependent variables further, Kruskal-Wallis H tests and Tukey HSD Post Hoc analysis indicated that the only significant EQ-dose effect on a dependent variable tested was the dementia self-rating scale, the AD8 (in contrast to the above ANCOVA which also reported a significant EQ-dose effect for Trail A). Analyses suggested that those tested at “EQ-dose: Three” reported significantly higher ratings of “dementia-related complaints” compared to “EQ-dose: One” and “EQ-dose: Two”, though there were no differences between “EQ-dose: None” and the other three EQ groups. To further investigate the relevance of any differences across earthquake groups, the neuropsychological test scores were normed within the groups and sample-specific Z-scores were generated. In this way, any differences found would hold more relevance than if these scores were converted to the (sometime) less reliable standard scores and, therefore, more reliable predictions could be made based on the multiple regression analyses that were performed.

Regression analysis confirmed that there was a predicted significant effect of medical condition, when the other dependent variables were controlled for on all neuropsychological test measures. Further, predicted variable analysis was somewhat influenced by education in the four (EQ-dose) by two (Sex) ANOVA due to males having significantly more years of education in EQ-dose: Three, and therefore improved significantly at EQ-dose: Three on all measures apart from Rey Copy. This led to an EQ-dose effect on measures of the MoCA, Rey Plan, Pentagons and AD8 and sex effects on all neuropsychological measures. Finally, an

analysis of age produced an interaction with EQ-dose which was found due to a predicted increase in performance on Rey Copy at “EQ-dose: Three” for younger participants, compared to older participants. Importantly, when these dependent variables are controlled for, an EQ-dose\*Medical Condition interaction is lost.

### **EQ-Dose Effect**

The Canterbury region has been through an unimaginable amount of disruptions, stress and frustrations since being sharply reminded of the unpredictable and unforgiving nature of being situated within the Pacific’s Rim of Fire. From loss and destruction resulting from countless earthquakes, to ongoing insurance battles, many residents have been pushed to their limits. But not everyone will have been affected equally; this thesis examined the consequences of these events on those who are considered to be the most vulnerable members of the population: the elderly. Norris et al. (2002a & 2002b) summarised twenty years of literature which indicated that there was a narrow focus on the research that is produced following disasters, which has been mainly centred on PTSD and depression, while very little attention has been given to the impact of stress on cognition.

The results presented in this thesis contribute to the field of both cognition and disaster research through its unique, albeit fortuitous design. The focal points were the largest of the numerous earthquakes to hit Canterbury during the year beginning in September 2010, and which represent an *absolute* stressor (Lupien et al., 2006), and whether these stressors produced changes in cognitive functioning in an elderly and potentially vulnerable population. Throughout the screening study, many older participants – indeed like their younger peers – made comments about their “quake brain”, and provided examples of “cognitive lapses” that had been plaguing them since the earthquakes had begun. For example, “lapses” could include forgetting why one had entered a room, struggling to think of a specific word, forgetting appointments, misplacing belongings such as keys, and so on. These anecdotes provided the initial interest, and also concern, as to whether those who were interviewed after the major earthquakes may be disadvantaged by the ongoing stress, and thus jeopardising the integrity of the cognition screening data that was being collected.

The AD8 dementia questionnaire (Appendix E) was the single measure which maintained a consistent EQ-dose effect through ANCOVA and multiple regression analysis. Participants were asked to decide whether they believed they had had problems with judgement, loss of interest in hobbies, repeating themselves, difficulties learning new tasks or

managing finances, forgetting the date or appointments or were experiencing daily problems with their memory (Galvin et al., 2005). However, only those who were interviewed at “EQ-dose: Three” (after all three major earthquakes) had significantly more complaints on the AD8 compared to those in the two EQ-dose groups before them, although there was no difference between these three EQ-dose groups and “EQ-dose: None” (as shown in Table 8). In other words, those who had been interviewed before any earthquakes did not have any less dementia-related complaints than any other group interviewed after the earthquakes commenced; when comparing EQ-dose groups, those experiencing the maximum number of major earthquakes (three) had significantly more complaints than those who had experienced one or two major earthquakes. Further, there was a significant effect of having a major medical condition, and through multiple regression, a major medical condition, age ( $>73$  years), sex (male) and Est-FSIQ ( $<111$ ) were all predictors of a significant effect on the AD8.

The first question to ask is whether the AD8 is a reliable measure of a participant’s self-rating of cognitive ability. Galvin, Roe, Coats, and Morris (2007) found significant correlations between the MMSE, the Short Blessed Test (SBT), the Clinical Dementia Rating, and participant’s self-rated AD8 score (albeit, to a lesser degree than an informant’s rating of the participants AD8), concluding that the AD8 “differentiates non-demented from demented individuals” (pg. 725), as long as these individuals are only mildly impaired. While interesting, there is much to be learnt about other factors that might influence an individual’s self-rating, or complaint, on a measure such as this; for example, many subjective complaints relating to cognition in the elderly are often attributed to depression (Kliegel, Zimprich & Eschen, 2005; Small et al., 2001; cited in Galvin et al., 2007). Therefore, if depression is related to an increase in complaints relating to cognition, it could reasonably be proposed that an increase in stress might have a similar effect.

The one neuropsychological test that did have a significant EQ-dose main effect (without an interaction) was the Trail Making Test A, a brief measure of several cognitive processes. This EQ-dose effect was not predicted when regression analysis was performed using all dependent variables (not just in a EQ-dose by Medical Condition ANCOVA, with Est-FSIQ as the covariate), however, and it is therefore likely that the initial analysis result was influenced by a number of poor performances among participants with a major medical condition (an EQ-dose\*Medical Condition interaction was close to significance,  $p = 0.080$ ).



These initial results therefore suggest that the only measure that was influenced by the stress of Canterbury's earthquakes was one that relied on participant's self-ratings, during a period where stress, cognition and "quake brain" were being discussed more frequently than usual. Galvin et al. (2005) indicate that a score of two or more out of a possible eight was predictive of some form of (at least) mild dementia. Table 3 indicated that there was only one sub-group who had a mean score of greater than 2 (those with a major medical condition in "EQ-dose: Three", mean = 2.27), and therefore all other subgroups mean scores would be considered 'normal', including the none-medical group in EQ-dose: Three (mean AD8 = 1.41). Nevertheless, it appears that mild changes, or cognitive complaints, were subjectively felt by participants in EQ-dose: Three, who were arguably more 'stressed', following a greater amount of 'stress', compared to those in EQ-dose: One and EQ-Dose: Two.

Two recent studies used subjective measures to analyse the effect that stress had on cognitive functioning. In both of these studies, greater reported cognitive disruption in university-aged participants (Helton et al., 2011), and higher reported stress in the last month in elderly males (Peters et al., 2011), were associated with worse performance on the SART and the MMSE, respectively. Further analyses on the AD8 would be required to investigate whether higher scores (equal to two or more out of eight) would have been associated with poorer performance on the neuropsychological test battery, and whether this would have had an influence on an EQ-dose effect. Or, people who report more stress also do less well on cognitive tests, that is, as part of their overall psychiatric state rather than their true performance. A preliminary one-way ANOVA suggests that an AD8 score greater than or equal to two was associated with poorer performance on the MoCA (there was a significant effect at the  $p < 0.05$  level [ $F(1, 588) = 9.002, p = 0.003$ ]), compared with an AD8 score less than two.

### **Medical Effect**

The main hypothesis was also concerned with whether a major medical condition exacerbated any EQ-dose effect. Having a major medical condition was associated with significantly poorer performance on many of the neuropsychological measures, and further, was associated with a poorer performance on the Rey Copy and Rey Recall at "EQ-dose: Two", following the second (most significant) earthquake, which had an arguably greater impact on the majority of the Canterbury region. This effect suggests one of two things: either these participants were already under increased stress associated with their medical condition,

which was exacerbated by the continued added stress of many earthquakes, or these participant's medical conditions had inversely affected their cognition before the earthquakes occurred. Another possibility is that as these participants were, on average, older than those without a medical condition, and therefore their cognitive functioning was already impaired (evidence to discount this theory is that there were no significant differences between Medical Condition groups on any of the neuropsychological measures before the commencement of the earthquakes, "EQ-dose: None").

Miller and O'Callaghan (2005) put forward several hypotheses as to how aging and stress combined to accelerate the aging of the hippocampus, which may help to explain why there was a significant Medical Condition effect. These four hypotheses, outlined earlier, described some combination of stress/increased glucocorticoids and aging as having a deleterious effect on the hippocampus and/or enhanced vulnerability to stress. Therefore, it could be hypothesised that having a medical condition increased vulnerability to stress and the effects of aging, and thus the added stress of the Canterbury earthquakes lead to a significant increase in dementia-related complaints (via the AD8), and specifically, a significant decline in function on the Rey Copy and Rey Recall following the devastating February 2011 earthquake ("EQ-dose: Two"), compared to an increase in function by those without a major medical condition.

Increased stress due to 'life events', and an association with decreased cognitive function, is a hypothesis that has been previously explored. In the current thesis, EQ-dose and Medical Condition are two factors which were considered as 'life events' but neuropsychological test performance was clearly more affected by a medical condition than an EQ-dose effect. Comijs et al. (2011) provided evidence for a negative association between cognitive function and life events such as death or illness of a partner, (grand)child, or relative, victim of crime and relocation, but did not examine illness/medical condition of the participant, nor natural or man-made disasters. Further, they did not find an association between cognitive function and an accumulation of life events, which the current thesis was also unable to provide evidence for in terms of an increase in EQ-dose over time (other than potentially on the AD8, which showed a significant increase in complaints at "EQ-dose: Three"). An improvement of the current thesis would be to include measures similar to Comijs et al. (2011), to look for associations between loss of loved ones, damage to property, stress due to insurance claim issues and how these 'stresses' would further impact on an EQ-

dose effect. IN addition, important variables that would have been interesting to obtain concern state measures of mood and anxiety, as well as general personality trait variables.

### **Sex, Age and Est-FSIQ**

Other demographic variables that were collected through the NZBRI's cognitive screening study included sex, age, and Est-FSIQ (calculated using sex, education and an occupation coding). The main interest in these variables was whether they would exacerbate an EQ-dose effect. The results suggest that there were sex effects on three neuropsychological tests, where males performed significantly better than females on Trail A and Rey Planning, while females performed better on the MoCA. There was, however, no interaction effect, and thus it is difficult to suggest that sex played a role in cognitive performance following repeated earthquakes. The research suggests that females would experience greater levels of emotional distress, trauma and mental health problems, compared to men following a disaster (Fothergill, 1998; Norris et al., 2002b), and no research has been clear on the cognitive consequences of males or females following a disaster. Though, one study that looked solely at males' performance on the MMSE did find that those with greater self-rated stress in the past month performed worse than those with lower stress ratings (Peters et al., 2011). There is no way of assessing participants rating of stress following the earthquakes they had experienced at the time of interviewing, and thus no conclusions can be drawn on this, yet this provides key information for the possibility of future research, and what should be included.

Age is a variable that has been consistently inconsistent, when comparing the effects of a disaster on 'younger' versus 'older' participants. The current thesis only found one age effect: those aged 74 and above performed significantly worse than those aged 65 to 73 on the MoCA (a finding consistent with other studies, suggesting that having a single cut-off score for "cognitive impairment" might include many 'healthy' older participants with age-appropriate cognitive changes; Kenny et al., 2013; Rossetti, Lacritz, Cullum, & Weiner, 2011). Two interaction effects, however, were observed: for the Rey Copy, older participants who had experienced all of the major earthquakes had significantly lower scores than the younger participants, and also the older participants in the earlier EQ-dose groups; while for the Pentagons, older participants had significantly lower scores following the first major

earthquake compared to younger participants, and compared to older participant in the other EQ-dose groups.

These results suggest that the older participants are more reactive to acute stressors in terms of certain cognitive functions such as attention and visuospatial planning, compared to younger participants. To provide any evidence for or against the “maturation hypothesis” or the “inoculation hypothesis” in terms of cognitive function, a younger cohort of participants would also need to be investigated and compared to the two age groups this thesis contrasted. These hypotheses were also related to psychological consequences and post-traumatic symptoms following a disaster (Ticehurst et al., 1996), making inferences about cognition, and how different age groups are affected, more difficult.

Finally, an Est-FSIQ effect was also investigated, by using a median split of the data. This was the closest approximation to socioeconomic status (SES) available, and it appeared that the MoCA and Rey (3min) Recall were affected by having an Est-FSIQ greater than 111, compared to having an Est-FSIQ less than 111. There was also one interaction effect, where those with a lower Est-FSIQ had significantly lower scores on the Rey Planning at “EQ-dose: Three” compared to those with a higher Est-FSIQ, and other participants with a lower Est-FSIQ at earlier testing points (EQ-dose: None, One and Two). This suggests a poorer method of planning the way in which the Rey Complex figure was initially copied, experienced by those who has experienced the greatest number of earthquakes, and who had an Est-FSIQ lower than the median of 111. It could broadly be assumed that a lower Est-FSIQ meant lower SES; this would infer that these participants had less quality housing in more vulnerable locations, and thus would be under greater stress following the earthquakes (Asgary & Willis, 1997); therefore, one could assume that Est-FSIQ was, in fact, more predictive of cognitive functioning following a major stressor than the other demographic variables of age and sex. However, predicted variable analysis indicated that there was indeed no predicted effect of the earthquake, defined by these variables, on cognitive functioning; whereas, a major medical condition was predicted, using these variables, to have a significant effect on each of the neuropsychological measures examined.

The results suggest several points of importance in the context of disaster research. When asked to rate their own cognitive functioning on a brief self-report questionnaire, participants who had experienced the greatest number of earthquakes at the time of testing, rated their cognition worse than others who had experienced fewer earthquakes before them.

Yet, there were relatively few other significant earthquake-related effects found by this analysis. Further, when age, sex and Est-FSIQ were used to predict an earthquake effect based on sample generated, normative data, there were no significant effects found for any of the neuropsychological measures used. However, having a major medical condition did significantly impact on cognitive functioning, and had an influence on an earthquake effect for some of the tests. Thus, there is good news and bad news to report: participants were not adversely affected by the major earthquakes that significantly affected the Canterbury region, no matter the sex, age or Est-FSIQ of the participant; however, it appears that having a major medical condition was predictive of significantly poorer cognitive functioning, and highlights the fact that a significant proportion of our elderly population may not be as resilient as some research in the past has tended to suggest.

### **Limitations, Improvements and Future Direction**

The current research was able to avoid many limitations that are usually found in disaster research, as described by Seplaki et al. (2006), including: small sample sizes; lack of health and demographic data; non-representative samples; and lack of longitudinal study designs. The nature of the NZBRI's cognitive screening study meant that there were large participant numbers, recruited from a wide variety of social, targeted and media networks in Canterbury, New Zealand, with a range of health and demographic data collected in a study design that enabled long-term follow-up. However, due to the fact that this screening study was developed and initiated before the first earthquake rocked the region, it is therefore necessary to highlight the areas of limitation that exist as a result.

Due to the unforeseen nature of disasters, the obvious measures that are missing from the current thesis include those of psychological distress such as anxiety, depression, trauma-related questionnaires, distress proneness and subjective measures of stress. Following the major earthquake in June, 2011, the Geriatric Depression Scale (Yesavage et al., 1982) and the Geriatric Anxiety Inventory (Pachana & Byrne, 2006) were added with ethics approval, however, this was done as a precaution to identify distress in participants who then may not have been suitable to continue with the study. Another question that was never asked was whether or not the participants interviewed for the screening study were in fact in the city or surrounding regions that were known to have felt the three major earthquakes of interest. One reassurance (purely for the sake of the study) would be that each participant was from the Canterbury region, and if they were not present for the three major earthquakes, they most

certainly would have been affected by the countless aftershocks, and ongoing disruptions that they have caused.

Subjective stress has been negatively correlated with cognitive performance (Helton et al., 2011; Peters et al., 2009) and would have at least been a beneficial measure to control for in the above analyses. Further, those who were most reactive to the stress caused by the earthquakes would have been predicted to have had greater cognitive dysfunction, and therefore, identifying these individuals and providing evidence for their reduced cognitive performance would give health and community services a targeted group of individuals to offer support to, potentially improving their quality of life in the months and years following the stressful events. This would also establish a good basis for follow-up research, for which there are the means to do so based on the longitudinal nature of the established screening study. Another limitation, related to stress, was that following the earthquakes, it could be argued that those who participated in the study were less impacted by the events which would indicate a self-selection bias.

Earlier, the role of measuring cortisol/endogenous glucocorticoids was discussed as a way of objectively measuring a stress response in an individual (Aguilar Cordero et al., 2014; Jelici et al., 2004; Lupien et al., 2007). It is generally accepted that stress induces a rise in these hormones; in an attempt to objectively measure the stress experienced by participants, the inclusion of salivary cortisol data might have improved the analysis of stress caused by the earthquakes. These analyses could have looked at whether participants with greater cortisol readings experienced greater cognitive dysfunction, compared to those with lower cortisol readings, or those interviewed before the earthquakes, or whether participants who had experienced the greater number of earthquakes at testing, had higher cortisol levels than those who had gone before them. This would have provided more conclusive evidence that there were physiological consequences of the stress hypothesised to have been present in those impacted on by the earthquakes.

In a lesson for future research on disasters, planning how to accurately assess the personal impact of a disaster may give more valuable information on who is most vulnerable. Predicted variable analysis using age, sex and Est-FSIQ did not establish an EQ-dose effect, though these variables themselves were predictive of changes in cognitive function and, therefore, other variables may be worth considering, such as the self-reported impact of the events, lost loved ones, financial costs associated with the disaster, displacement and loss of

homes or businesses. These variables are harder to measure, and thus future research needs to be done to establish questionnaires that accurately, but succinctly, quantify these losses in a way that can be analysed against other participants. Socioeconomic status is another variable that was not included, and though close to Est-FSIQ, would provide more valuable information on an individuals predicted susceptibility to the impact of a disaster.

Therefore, the current thesis not only provides a unique chance to assess the impact of randomly occurring major disruptions to individuals throughout a community, but it also highlights areas of opportunity to improve the way in which disaster research is carried out. While focusing on cognitive functioning, which has had very limited previous exposure, has provided a first-hand look at an often ignored consequence of disasters, it highlights the fact that this is a complicated process to focus on. To improve this research, more information is required about the individual, including how they were affected (on many levels), what their living situation was like before the disaster, and how prone they were to the psychological consequences of such a traumatising event. All of these variables will provide a much more detailed context for which to be able to draw more concrete conclusions about the impact that these events may have on different members of our communities.

As for this thesis, there are now opportunities to expand and to continue to assess the impact that these historic earthquakes have had on the more vulnerable members of the population. Dementia will continue to grow in incidence over the next twenty years as the baby boomers continue to age and reach retirement. The long term consequences of these earthquakes are a relative unknown and thus surveillance may be the key to early identification and management of any issues that may arise. Cognition is not the only consequence of concern: depression, anxiety, and post-traumatic stress are all concerning features of a stressful event, and measures for these could be included in future follow-up interviews. Further, those under the age of 65 who were not screened for this study are not immune to the cognitive changes that occur during the onset of dementia, and these are the next generation of retirees; therefore, including a younger cohort in future research would be encouraged. The NZBRI and the University of Canterbury are in an invaluable position to continue to monitor and contribute to the growing field of disaster research as a result of the Canterbury earthquakes, and this thesis provides a starting point to monitor those included in the study, and it is hoped that targeted interventions are the ultimate goal in the future.

## **Conclusion**

Disasters can occur anytime, anywhere, and by many different means. Disasters also impact on the lives of every member of the population. What needs to be done as a community is to identify individuals who may be more vulnerable to the impact that these events can have, and to offer early interventions to minimize the consequences that can manifest acutely, and in the future. This thesis aimed to contribute to the literature on the cognitive consequences of ongoing exposure to the stress caused by repeated earthquakes. From September 2010 to June 2011, three major earthquakes, and countless smaller, but no less stress-inducing aftershocks continuously rocked the Canterbury region. This thesis hypothesised whether repeated major earthquake exposure would decrease cognition performance (an EQ-dose effect), and further, whether a major medical condition, sex, age or Est-FSIQ would further exacerbate an EQ-dose effect.

Residents from the Canterbury region would be relieved to note that an EQ-dose effect was not only limited to that of the AD8, and to a lesser extent the Trail A, but it was also not possible to predict an EQ-dose effect based on the variables this thesis had available. The AD8, a self-report dementia questionnaire was one variable that maintained an EQ-dose effect when looking at dependent variable analysis; however, there was no difference between the post-earthquake groups and the pre-earthquake group. EQ-dose: Three was significantly different to EQ-dose: One and Two, and this is likely best explained by the medical condition group in EQ-dose: Three. This might provide the most important finding: those with a major medical condition are more likely to self-report changes in cognition, and perform significantly worse on a range of neuropsychological tests, compared to those without a major medical condition. Therefore, this thesis has identified a group that has been significantly impacted by the continued earthquakes, and they are the elderly, who were already experiencing the continued stress of a chronic or serious illness at the time of interviewing.

Further, it is possible that those who rated their cognition as worse off were going through serious ongoing upheaval due to earthquake damage to their homes, roads and infrastructure, and local businesses. This in turn leading to stress caused by insurance claims, daily disruptions to day-to-day activities, displacement, and for the very unfortunate few, the impact of loss of life. As we do not know objectively which participants were impacted more than others, it is difficult to make conclusions about the above results in terms of specific impact; however, we can conclude that those participants, who had experienced the greatest number of major earthquakes, did have a significantly higher AD8 self-rating (compared to



those who had experienced fewer earthquakes). But the question remains: is it permanent and progressive changes expected in dementia; or is this a reaction to the personal upheaval that Cantabrians dealt with in the period following the earthquake.

The term “quake brain” provided Cantabrians with an excuse for their momentary lapses in memory and attention that was reported often during interviewing. This thesis provided very little evidence for its existence when just considering an EQ-dose effect on the core measures of neuropsychological functioning. Further investigations into those who had significantly higher ratings on the AD8 might unearth greater physical disruptions as a result of the earthquakes, such as having decisions made on the status of their properties, requiring relocation and rebuilding. Nevertheless, with such limited research into the area of disasters and cognition, it is important to identify the phenomenon. Participants underwent a large amount of stress, and though they complained of cognitive dysfunction, there appears to be more evidence to suggest a general resilience, than there is to suggest an EQ-dose effect.

The elderly population of Canterbury never thought they would see their region devastated by so many earthquakes; they were unprepared and many were suffering from major or ongoing medical conditions. Many saw the NZBRI screening study as an opportunity to examine their cognition which they felt had been impacted by the stress of these earthquakes, yet the impact appears to be minor. A participants medical status, age, sex and Est-FSIQ were all more predictive of cognitive performance than was the number of earthquakes experienced, and this information is invaluable when looking at the way our elderly population react to major stressors. These variables are easy to measure (compared to subjective or objective measures of stress impact), and may prove to be as useful when evaluating cognitive consequences of major stress. Further research is required to evaluate the effect that specific earthquake-related loss and disruption had on individuals; but until then, researchers may continue to use accurate and varied health and demographic information as significant predictors of cognitive performance in the elderly who experience major stress-inducing events, such as the devastating Canterbury earthquakes.

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## Appendix A: Recruitment Newspaper Article



### **Volunteers sought for study of memory, attention and language**

Researchers at the Van der Veer Institute for Parkinson's and Brain Research are seeking volunteers aged 65 years and over for a research study. The study will determine the average performance for older adults in an assessment that tests memory, thinking, attention and language. The aim being to look at ways to better understand and combat Parkinson's disease and Alzheimer's disease, brain disorders which are common in the elderly and only becoming more common as the population of retired individuals continues to rise in New Zealand.

The study will involve one forty minute session at the Van der Veer Institute (66 Stewart Street, by Hagley High School). This brief assessment can also be conducted in your home if preferred. This will involve doing a series of entertaining puzzles and exercises designed to test your naming, memory, attention and language abilities.

Furthermore, you will be given the opportunity to be a part of a database of older people who can be contacted to participate in further new research studies that are currently being undertaken at the Van der Veer Institute. These studies look to find the causes and possible therapies that will help those with problems in memory and thinking in later life, using novel and interactive activities or brain imaging technology.

The study has received ethical approval from the Upper South Regional Ethics Committee.

We would greatly value your help with this study. If you are interested in taking part or require further information please phone or email Leslie Livingston, whose details are listed below.

Leslie Livingston

Van der Veer Institute for Parkinson's and Brain Research

66 Stewart Street, Christchurch

Phone: (03) 378 6257

Email: [leslie.livingston@vanderveer.org.nz](mailto:leslie.livingston@vanderveer.org.nz)

## **Appendix B: Participant Information**

### **Memory, attention and language in older people**

You are invited to participate in a study that will look at memory, attention and language in older people in Canterbury.

To take part in this study you must be over 65 and do not have a history of neurological problem, such as severe head injury, stroke or Parkinson's disease.

#### **What will you have to do if you participate in this study?**

If you choose to participate you will undergo testing for a period of about thirty minutes. This test will be conducted at the Van der Veer Institute, 66 Stewart Street, or in your home, as preferred.

You will be asked questions concerning your memory, attention and language. Some tasks require verbal answers and others require pen and paper answers. Using your responses to a few other questions, we will also make a digital recording so that we can assess spoken language in older people, but you can choose not to have this recording made if you prefer.

You will also be asked if you wish to be part the Van der Veer Institute's volunteer database (this consent would be voluntary – that is, your choice). If you agree, you may be contacted again to participate in further research studies that have been given ethical approval (for example, a study on “cognitive enrichment for older people” or brain imaging studies.)

As part of this study we will ask you for relevant information, such as your date of birth, and your previous medical history. You can also indicate your ethnicity, if you agree. You will also be asked if you consent for your GP to being informed about your participation in this study.

#### **Benefits and Risks**

The tests are designed in a way that will minimise any tiredness or distress. If this occurs, testing will discontinue immediately.

No direct benefits are expected for the participants who take part in this study.

#### **Participation**

Participation in the study is voluntary (your choice). You can take as much time as you need to decide whether you want to participate in this study. Your family/whanau may be involved in the decision on whether to take part. If you agree to take part, you are free to withdraw from at any stage.

If you decide to accept the invitation to participate in this study please contact Leslie Livingston by phone on (03) 378 6257 or via email to [leslie.livingston@vanderveer.org.nz](mailto:leslie.livingston@vanderveer.org.nz).

#### **You're Rights**

The results will be kept confidential. Your information will be coded by a number known only to the investigators. No material that could personally identify you will be used in any reports on this study.

If you wish, we will send you a summary of the results of this study. It may take some time for us to collect and analyse all of the data. The data will be stored securely for twenty years.

This project has received ethical approval from the Upper South A Regional Ethics Committee. The investigator agrees to an approved auditor, appointed by the Upper South A Regional Ethics Committee or their approved representative, reviewing relevant records for the sole purpose of checking the accuracy of the information recorded for the study.

**If you have any questions or concerns about your rights as a participant in this research study you can contact an independent health and disability advocate. This is a free service provided under the Health and Disability Commissioner Act.**

- \* **Telephone: (NZ wide) 0800 555 050**
- \* **Free Fax (NZ wide): 0800 2787 7678 (0800 2 SUPPORT)**
- \* **Email (NZ wide): [advocacy@hdc.org.nz](mailto:advocacy@hdc.org.nz)**

#### **Any questions or queries**

If you have any questions, please phone Leslie Livingston (Study Co-ordinator) by phone on (03) 378 6257 or via email to [leslie.livingston@vanderveer.org.nz](mailto:leslie.livingston@vanderveer.org.nz).

#### **Contact details for Principal Investigator:**

Associate Professor John Dalrymple-Alford, Van der Veer Institute (03) 378 6090 or University of Canterbury (03) 364 2998 extn. 6998

#### **Co-Investigators:**

Hannah Farr, Van der Veer Institute and University of Canterbury  
Yan Chen (Amy) Wang, Van der Veer Institute and University of Canterbury  
Leslie Livingston, Van der Veer Institute, and University of Otago  
Simon Donaldson, Van der Veer Institute and University of Canterbury  
Professor Tim Wilkinson, University of Otago  
Dr. Richard Watts, Van der Veer Institute and University of Canterbury  
Professor Richard Porter, University of Otago  
Dr. Margaret Maclagan, University of Canterbury  
Dr Megan McAuliffe, University of Canterbury  
Professor Tim Anderson, Van der Veer Institute and University of Otago

## Appendix C: Participant Checklist

General Checklist for Cognitive Screening (older people)

M / F

You Enter Today's Date:

Tell me your Full Name:	Study ID #:
What is your Date of birth:	Daytime Tel?
Today: Do you wear reading glasses? (Yes / No)	Handedness:
Do you wear a hearing aid (if relevant, are you wearing it now)? (Yes / No)	R / L

Do you have a spouse or live with a significant other? ( Yes / No )

<p><u>Did you bring a list of Current medications?</u> Yes / No (<i>if not, then we'll phone</i>)</p> <p>Bladder Antispasmodics?</p> <p>Gastrointestinal Antispasmodics?</p> <p>Central Anticholinesterases?</p> <p>First Generation Antihistamines?</p> <p>Antipsychotics?</p> <p>Sleep medication?</p> <p>Pain medication?</p>
--

**DO NOT ASK (GO TO NEXT PAGE): Leslie will check – by phone – whether any below apply**

- ☐ Age today (normal exclusion): Aged < 65
- ☐ Have you ever had a stroke, or moderate or severe head injury, or other neurological issue such as multiple sclerosis or epilepsy?  
(specify:\_\_\_\_\_)
- ☐ Have you ever had Neurosurgery
- ☐ Have you had a major medical illness, such as cardiovascular; diabetes req insulin; severe migraine; other:\_\_\_\_\_)
- ☐ Have you ever been hospitalized for any psychiatric illness?  
(specify:\_\_\_\_\_)
- ☐ Have you had help for depression in last 6 months (treatment or counselling)?
- ☐ Ever had problems with alcohol or illegal substances?
- ☐ Did you have any special learning problems at school?

## Appendix D: Consent Form

*“Memory, attention and language in older people”*

I have read and understood the information sheet dated 03 May 2010 for volunteers taking part in the study designed to gather data about thinking, memory and language in older people in Canterbury. I have had time to consider whether to take part.

I have had the opportunity to discuss this study, and I am satisfied with the answers I have been given. I have had the opportunity to use whanau (family) support or a friend to help me ask questions and understand the study. I further understand that taking part in this study is completely voluntary (my choice) and that I may withdraw from participation in this study at any time, and this will in no way affect my future health care.

I understand that participation in this study is confidential and that no material which could identify me will be used in any reports of this study.

I know who to contact if I have any questions or problems about the study.

I consent to my GP being informed of my participation in this study.....YES/NO

Name of GP.....

I wish to receive a copy of the results.....YES/NO

I consent to the information gathered about me being used for future research into studies related to memory, attention and language (subject to ethical approval being given by a New Zealand accredited ethics committee).....YES/NO

I wish to be part of the Van der Veer Institute’s volunteer database.....YES/NO

I \_\_\_\_\_ (full name) hereby consent to take part in this study, and understand that by agreeing to be part of a volunteer database that I could be contacted again for another research study. I also understand that if I am contacted again, that I do not have to participate in that study.

Signature of Participant\_\_\_\_\_

Signature of witness\_\_\_\_\_

Project explained by\_\_\_\_\_

Project role\_\_\_\_\_

## Appendix E: AD8 Questionnaire

<b>Repeat:</b> Remember, “Yes, a change” indicates that there has been a change in the last 3-4 years caused by cognitive (thinking and memory) problems	YES, A change	NO, change	N/A, Don’t know
First Question:			
1. Have you had any Problems with judgement (e.g. problems making decisions, bad financial decisions, problems with thinking)			
2. Less interests in hobbies/activities			
3. Repeat the same things over and over (questions, stories, or statements)			
4. Trouble learning how to use a tool, appliance or gadget (e.g. VCR, computer, microwave, remote control)			
5. Forget the correct month or year			
6. Trouble handling complicated financial affairs (e.g. balancing checkbook, income taxes, paying bills)			
7. Trouble remembering appointments			
8. Daily problems with thinking and/or memory			
Total AD8 score			

*Once all 8 complete, then ask for a brief example or reason that they can think of for any “change” answers, except for #5. Check it is a change to previous!*

Adapted from Galvin, J. E., et al. (2005). The AD8, a brief informant interview to detect dementia, *Neurology*, 65, 559-564.

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## Appendix F: Script for Recorded Speech Section

Recorded on behalf of Dr. Margaret Maclagan and Assoc. Prof Megan McAuliffe, Department of Communication, University of Canterbury.

**Now, if you agree, I'd like to record you speaking for a few minutes.**

**We're compiling a database of the way New Zealanders speak.**

If agreed, **"Good"**. Turn on (side to left), then press the 'record button' once (it will blink).

Then ask: **"Please read this sentence."** (i.e. give the first grandfather sentence).

Then push record button again (light now remains on, timer will start, recording underway)

The YOU say THE PARTICIPANT NUMBER AND DATE. THEN SAY:

**Please count to ten.**

**Now tell me about an early, happy childhood memory?**

If none, prompt with "do you recall anything from when you were about 10 years old?" If too little, then say, "Do you remember anything else?" or "What happened next?" Aiming for about 2 mins.

Only if < 30s for above Qs, ask: Tell me a little about your family (truncate after 2 mins).

**Thank you.** Then, count two secs, and without warning:

**"What did you have for breakfast?"** (assuming answer <60 secs, then next one too)

**"What do you like best for breakfast?"**

**"We're nearly finished. [pause] Are you OK?"** [response from P]

Then say, **"Could you read this passage please – it's not a test of reading skill so you might like to look at it first. Let me know when you are ready to read it aloud.**

Give the passage (next page) to the participant (allow to read). Prompt with "Ready?" if still reading after 2 mins.

After they have read it aloud, say,

**"We're done. It went OK, didn't it?"** [response from P]

**"So, which test was the hardest?"** [response from P]

Then push the stop button on the recorder, and say,

**"Thank you very much! We will be in touch, although it may be two to three months, depending on how busy we are."**

## **Appendix G**

### **The Grandfather Passage**

You wish to know all about my grandfather. Well, he is nearly ninety-three years old; yet he still thinks as swiftly as ever. He dresses himself in an old black frock coat, usually with several buttons missing. A long beard clings to his chin, giving those who observe him a pronounced feeling of the utmost respect. Twice each day he plays skilfully and with zest upon a small organ. Except in the winter when the snow or ice prevents, he slowly takes a short walk in the open air each day. We have often urged him to walk more and smoke less, but he always answers, “Banana oil!” Grandfather likes to be modern in his language.